COMPAQ

Parallel Database Cluster Model PDC/O2000 for Oracle8*i* and Windows 2000

Administrator Guide

Second Edition (June 2001)
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Compaq Computer Corporation

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Parallel Database Cluster Model PDC/02000 for Oracle8*i* and Windows 2000
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About This Guide

Purpose

This administrator guide provides information about the planning, installation, configuration, implementation, management, and troubleshooting of the Compaq Parallel Database Cluster Model PDC/O2000 running Oracle8*i* software on the Microsoft Windows 2000 Advanced Server operating system.

Audience

The expected audience of this guide consists primarily of MIS professionals whose jobs include designing, installing, configuring, and maintaining Compaq Parallel Database Clusters.

The audience of this guide must have a working knowledge of Microsoft Windows 2000 Advanced Server and of Oracle databases or have the assistance of a database administrator.

This guide contains information for network administrators, database administrators, installation technicians, systems integrators, and other technical personnel in the enterprise environment for the purpose of cluster planning, installation, implementation, and maintenance.

IMPORTANT: This guide contains installation, configuration, and maintenance information that can be valuable for a variety of users. If you are installing the PDC/O2000 but will not be administering the cluster on a daily basis, please make this guide available to the person or persons who will be responsible for the clustered servers after you have completed the installation.

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Scope

This guide offers significant background information about clusters as well as basic concepts associated with designing clusters. It also contains detailed product descriptions and installation steps.

This administrator guide is designed to assist you in the following objectives:

- Understanding basic concepts of clustering technology
- Recognizing and using the high-availability features of the PDC/O2000
- Planning and designing a PDC/O2000 cluster configuration to meet your business needs
- Installing and configuring PDC/O2000 hardware and software
- Managing the PDC/O2000
- Troubleshooting the PDC/O2000

The following summarizes the contents of this guide:

- Chapter 1, "Clustering Overview," provides an introduction to clustering technology features and benefits.
- Chapter 2, "Cluster Architecture," describes the hardware components of the PDC/O2000 and provides detailed I/O path configuration information.
- Chapter 3, "Cluster Software Components," describes software components used with the PDC/O2000.
- Chapter 4, "Cluster Planning," outlines an approach to planning and designing cluster configurations that meet your business needs.
- Chapter 5, "Installation and Configuration," outlines the steps you will take to install and configure the PDC/O2000 hardware and software.
- Chapter 6, "Cluster Management," includes techniques for managing and maintaining the PDC/O2000.
- Chapter 7, "Troubleshooting," contains troubleshooting information for the PDC/O2000.
- Appendix A, "Diagnosing and Resolving Shared Disk Problems," describes procedures to diagnose and resolve shared disk problems.
- Glossary contains definitions of terms used in this guide.

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Some clustering topics are mentioned, but not detailed, in this guide. For example, this guide does not describe how to install and configure Oracle8*i* on a cluster. For information about these topics, see the documents referenced in the guide sections or refer to the documentation provided with the Oracle software.

Referenced Manuals

For additional information, refer to documentation related to the specific hardware and software components of the Compaq Parallel Database Cluster. These related manuals include, but are not limited to:

- Documentation related to the ProLiant servers you are clustering (for example, guides, posters, and performance and tuning guides)
- Compaq StorageWorks documentation
  - *Compaq StorageWorks RAID Array 4000 User Guide*
  - *Compaq StorageWorks RAID Array 4100 User Guide*
  - *Compaq StorageWorks Fibre Channel Storage Hub 7 Installation Guide*
  - *Compaq StorageWorks Fibre Channel Storage Hub 12 Installation Guide*
  - *Compaq StorageWorks Fibre Channel Host Bus Adapter Installation Guide*
  - *Compaq StorageWorks 64-Bit/66-MHz Fibre Channel Host Adapter Installation Guide*
- Microsoft Windows 2000 Advanced Server documentation
  - *Microsoft Windows 2000 Advanced Server Administrator's Guide*

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- Oracle8*i* documentation, including:
  - *Oracle8i Parallel Server Setup and Configuration Guide*
  - *Oracle8i Parallel Server Concepts*
  - *Oracle8i Parallel Server Administration, Deployment, and Performance*
  - *Oracle Enterprise Manager Administrator's Guide*
  - *Oracle Enterprise Manager Configuration Guide*
  - *Oracle Enterprise Manager Concepts Guide*

Supplemental Documents

The following technical documents contain important supplemental information for the Compaq Parallel Database Cluster Model PDC/O2000:

- *Supported Ethernet Interconnects for Compaq Parallel Database Clusters Using Oracle Parallel Server* (ECG062/0299), at

  www.compaq.com/support/techpubs/whitepapers

- *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000*, at

  www.compaq.com/enterprise/ha-pdc.html

- Various technical white papers on Oracle and cluster sizing, which are available from Compaq ActiveAnswers website, at

  www.compaq.com/activeanswers

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Text Conventions

This document uses the following conventions to distinguish elements of text:

User Input, GUI Selections	Text a user types or enters appears in boldface. Items a user selects from a GUI, such as tabs, buttons, or menu items, also appear in boldface. User input and GUI selections can appear in uppercase and lowercase letters.
File Names, Command Names, Directory Names, Drive Names	These elements can appear in uppercase and lowercase letters.
Menu Options, Dialog Box Names	These elements appear in initial capital letters and may appear in bold for emphasis.
Type	When you are instructed to *type* information, type the information **without** pressing the **Enter** key.
Enter	When you are instructed to *enter* information, type the information and then press the **Enter** key.

Symbols in Text

These symbols may be found in the text of this guide. They have the following meanings:

WARNING: Text set off in this manner indicates that failure to follow directions in the warning could result in bodily harm or loss of life.

CAUTION: Text set off in this manner indicates that failure to follow directions could result in damage to equipment or loss of information.

IMPORTANT: Text set off in this manner presents clarifying information or specific instructions.

NOTE: Text set off in this manner presents commentary, sidelights, or interesting points of information.

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Symbols on Equipment

These icons may be located on equipment in areas where hazardous conditions may exist.

Any surface or area of the equipment marked with these symbols indicates the presence of electrical shock hazards. Enclosed area contains no operator serviceable parts.

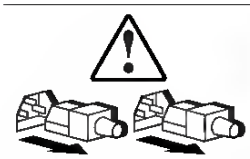
WARNING: To reduce the risk of injury from electrical shock hazards, do not open this enclosure.

Any RJ-45 receptacle marked with these symbols indicates a Network Interface Connection.

WARNING: To reduce the risk of electrical shock, fire, or damage to the equipment, do not plug telephone or telecommunications connectors into this receptacle.

Any surface or area of the equipment marked with these symbols indicates the presence of a hot surface or hot component. If this surface is contacted, the potential for injury exists.

WARNING: To reduce the risk of injury from a hot component, allow the surface to cool before touching.



Power Supplies or Systems marked with these symbols indicate the equipment is supplied by multiple sources of power.

WARNING: To reduce the risk of injury from electrical shock, remove all power cords to completely disconnect power from the system.

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Rack Stability

WARNING: To reduce the risk of personal injury or damage to the equipment, be sure that:

- The leveling jacks are extended to the floor.
- The full weight of the rack rests on the leveling jacks.
- The stabilizing feet are attached to the rack if it is a single rack installations.
- The racks are coupled together in multiple rack installations.
- Only one component is extended at a time. A rack may become unstable if more than one component is extended for any reason.

Getting Help

If you have a problem and have exhausted the information in this guide, you can get further information and other help in the following locations.

Compaq Technical Support

In North America, call the Compaq Technical Phone Support Center at 1-800-OK-COMPAQ. This service is available 24 hours a day, 7 days a week. For continuous quality improvement, calls may be recorded or monitored.

Outside North America, call the nearest Compaq Technical Support Phone Center. Telephone numbers for worldwide Technical Support Centers are listed on the Compaq website. Access the Compaq website by logging on to the Internet at

www.compaq.com

Be sure to have the following information available before you call Compaq:

- Technical support registration number (if applicable)
- Product serial number
- Product model name and number
- Applicable error messages
- Add-on boards or hardware
- Third-party hardware or software
- Operating system type and revision level

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Compaq Website

The Compaq website has information on this product as well as the latest drivers and Flash ROM images. You can access the Compaq website by logging on to the Internet at

www.compaq.com

Compaq Authorized Reseller

For the name of your nearest Compaq Authorized Reseller:

- In the United States, call 1-800-345-1518.
- In Canada, call 1-800-263-5868.
- Elsewhere, see the Compaq website for locations and telephone numbers.

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Chapter 1

Clustering Overview

For many years, companies have depended on clustered computer systems to fulfill two key requirements: to ensure users can access and process information that is critical to the ongoing operation of their business, and to increase the performance and throughput of their computer systems at minimal cost. These requirements are known as **availability** and **scalability**, respectively.

Historically, these requirements have been fulfilled with clustered systems built on proprietary technology. Over the years, open systems have progressively and aggressively moved proprietary technologies into industry-standard products. Clustering is no exception. Its primary features, availability and scalability, have been moving into client/server products for the last few years.

The absorption of clustering technologies into open systems products is creating less expensive, non-proprietary solutions that deliver levels of function commonly found in traditional clusters. While some uses of the proprietary solutions will always exist, such as those controlling stock exchange trading floors and aerospace mission controls, many critical applications can reach the desired levels of availability and scalability with non-proprietary client/server-based clustering.

These clustering solutions use industry-standard hardware and software, thereby providing key clustering features at a lower price than proprietary clustering systems. Before examining the features and benefits of the Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000), it is helpful to understand the concepts and terminology of clustered systems.

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Clusters Defined

A cluster is an integration of software and hardware products that enables a set of loosely coupled servers and shared storage subsystem components to present a single system image to clients and to operate as a single system. As a cluster, the group of servers and shared storage subsystem components offers a level of availability and scalability far exceeding that obtained if each cluster node operated as a stand-alone server.

The PDC/O2000 uses the Oracle8*i* Parallel Server software, which is a parallel database that can distribute its workload among the cluster nodes. Refer to Chapter 3, "Cluster Software Components" to determine the specific releases your cluster kit supports.

Figure 1-1 shows an example of a PDC/O2000 that includes two nodes (*ProLiant*™ servers), two Compaq StorageWorks RAID Array 4000s or 4100s (RA4000/RA4100 Arrays), two Compaq *StorageWorks*™ Fibre Channel Storage Hubs, Compaq StorageWorks FC-AL Switches, or Compaq StorageWorks Fibre Channel SAN Switches, a cluster interconnect, and a client local area network (LAN).

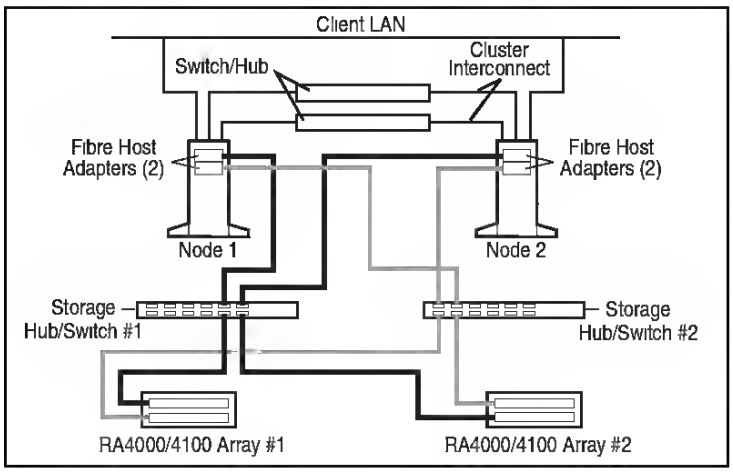

Figure 1-1. Example of a two-node Compaq Parallel Database Model PDC/O2000 cluster

The PDC/O2000 can use redundant Fibre Channel Fabric Storage Area Network (SAN) and redundant Fibre Channel Arbitrated Loop (FC-AL) SAN topologies. These two SAN topologies support the use of multiple redundant fabrics or loops, respectively. In the example shown in Figure 1-1, the clustered nodes are connected to the database on the shared storage subsystems through a redundant Fibre Channel Fabric or redundant FC-AL. Clients access the database through the client LAN, and the cluster nodes communicate across an Ethernet cluster interconnect.

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Availability

When computer systems experience outages, the amount of time the system is unavailable is referred to as **downtime**. Downtime has several primary causes: hardware faults, software faults, planned service, operator error, and environmental factors. Minimizing downtime is a primary goal of a cluster.

Simply defined, **availability** is the measure of how well a computer system can continuously deliver services to clients.

Availability is a system-wide endeavor. The hardware, operating system, and applications must be designed for availability. Clustering requires stability in these components, then couples them in such a way that failure of one item does not render the system unusable. By using redundant components and mechanisms that detect and recover from faults, clusters can greatly increase the availability of applications critical to business operations.

Scalability

Simply defined, **scalability** is a computer system characteristic that enables improved performance or throughput when supplementary hardware resources are added. Scalable systems allow increased throughput by adding components to an existing system without the expense of adding an entire new system.

In a stand-alone server configuration, scalable systems allow increased throughput by adding processors or more memory. In a cluster configuration, this result is usually obtained by adding cluster nodes.

Not only must the hardware benefit from additional components, but also software must be constructed in such a way as to take advantage of the additional processing power. Oracle8*i* Parallel Server distributes the workload among the cluster nodes. As more nodes are added to the cluster, cluster-aware applications can use the parallel features of Oracle8*i* Parallel Server to distribute workload among more servers, thereby obtaining greater throughput.

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Compaq Parallel Database Cluster Overview

As traditional clustering technology has moved into the open systems of client/server computing, Compaq has provided innovative, customer-focused solutions. The PDC/O2000 moves client/server computing one step closer to the capabilities found in expensive, proprietary cluster solutions, at a fraction of the cost.

The PDC/O2000 combines the popular Microsoft Windows 2000 Advanced Server operating system and the industry-leading Oracle8*i* Parallel Server with award-winning Compaq ProLiant servers and shared storage subsystems.

Together, these hardware and software components provide improved performance through a truly scalable parallel application and improved availability using clustering software that rapidly recovers from detectable faults. These components also provide improved availability through concurrent multinode database access using Oracle8*i* Parallel Server.

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Chapter 2

Cluster Architecture

The Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000) is an integration of a number of different hardware and software products. This chapter discusses how these products play a role in bringing a complete clustering solution to your computing environment.

The hardware products include:

- Compaq ProLiant servers
- Shared storage components
  - Compaq StorageWorks RAID Array 4100s (RA4100 Arrays) or Compaq StorageWorks RAID Array 4000s (RA4000 Arrays)
  - Two Compaq StorageWorks RAID Array 4000 Controllers (RA4000 Array Controllers) installed in eacb RA4000 Array or RA4100 Array
  - Compaq StorageWorks Fibre Channel SAN Switches (Fibre Channel SAN Switches) for redundant Fibre Channel Fabrics
  - Compaq StorageWorks Storage Hubs (Storage Hubs) or Compaq StorageWorks FC-AL Switches (FC-AL Switches) for redundant Fibre Channel Arbitrated Loops
  - Compaq StorageWorks 64-bit/66 MHz Fibre Channel Host Adapters or Compaq StorageWorks Fibre Channel Host Adapter/Ps (Fibre Host Adapters) installed in each server
  - Gigabit Interface Converter-Shortwave (GBIC-SW) modules
  - Fibre Channel cables

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- Cluster interconnect components
  - Ethernet NIC adapters
  - Ethernet cables
  - Ethernet switches/hubs

The software products include:

- Microsoft Windows 2000 Advanced Server with Service Pack 1 or later
- Compaq drivers and utilities
- Oracle8*i* Enterprise Edition with the Oracle8*i* Parallel Server Option

Refer to Chapter 3, "Cluster Software Components," for a description of the software products used with the PDC/O2000.

Compaq ProLiant Servers

A primary component of any cluster is the server. Each PDC/O2000 consists of two or more cluster nodes. Each node is a Compaq ProLiant server.

With some exceptions, all nodes in a PDC/O2000 cluster must be identical in model. In addition, all components common to all nodes in a cluster, such as memory, number of CPUs, and the interconnect adapters, must be identical and identically configured.

NOTE: Certain restrictions apply to the server models and server configurations that are supported by the PDC/O2000. For a current list of PDC-certified servers and details on supported configurations, refer to the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* at

www.compaq.com/solutions/enterprise/ha-pdc.html

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High-Availability Features of ProLiant Servers

In addition to the increased application and data availability enabled by clustering, ProLiant servers include many reliability features that provide a solid foundation for effective clustered server solutions. The PDC/O2000 is based on ProLiant servers, most of which offer excellent reliability through redundant power supplies, redundant cooling fans, and Error Checking and Correcting (ECC) memory. The high-availability features of ProLiant servers are a critical foundation of Compaq clustering products. Table 2-1 lists the high-availability features found in many ProLiant servers.

Table 2-1
High-Availability Components of ProLiant Servers

Hot-pluggable hard drives	Redundant power supplies
Digital Linear Tape (DLT) Array (optional)	ECC-protected processor-memory bus
Uninterruptible power supplies (optional)	Redundant processor power modules
ECC memory	PCI Hot Plug slots (in some servers)
Offline backup processor	Redundant cooling fans

Shared Storage Components

The PDC/O2000 is based on a cluster architecture known as "shared storage clustering," in which clustered nodes share access to a common set of shared disk drives. For the PDC/O2000, the shared storage includes these hardware components:

- RA4000 Arrays or RA4100 Arrays
- RA4000 Array Controllers
- Fibre Channel SAN Switches for each redundant Fibre Channel Fabric

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- Storage Hubs or FC-AL Switches for each redundant Fibre Channel Arbitrated Loop (FC-AL)
- Fibre Host Adapters
- Gigabit Interface Converter-Shortwave (GBIC-SW) modules
- Fibre Channel cables

RA4000 Array

The RA4000 Array is one shared storage solution for the PDC/O2000. Each redundant Fibre Channel Fabric or redundant FC-AL supports one or more RA4000 Arrays. Each RA4000 Array contains two single-port RA4000 Array Controllers. Each array controller connects the RA4000 Array to one Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch.

The RA4000 Array can hold up to twelve 1-inch or eight 1.6-inch Wide-Ultra SCSI drives. The drives must be mounted on Compaq hot-pluggable drive trays. SCSI IDs are assigned automatically according to their drive location, allowing 1-inch and 1.6-inch drives to be intermixed within the same RA4000 Array.

The RA4000 Array comes in either a rack-mountable or a tower model.

For more information about the RA4000 Array, refer to the *Compaq StorageWorks RAID Array 4000 User Guide*.

RA4100 Array

The RA4100 Array is another shared storage solution for the PDC/O2000. Each redundant Fibre Channel Fabric or redundant FC-AL supports one or more RA4100 Arrays. Each RA4100 Array contains two single-port RA4000 Array Controllers. Each array controller connects the RA4100 Array to one Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch.

The RA4100 Array can hold up to twelve 1-inch Compaq Hot Plug Ultra2 Disk Drives. The drives must be mounted on Compaq hot-pluggable drive trays. SCSI IDs are assigned automatically according to their drive location.

The RA4100 Array comes in a rack-mountable model.

For more information about the RA4100 Array, refer to the *Compaq StorageWorks RAID Array 4100 User Guide*.

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RA4000 Array Controllers

To ensure redundant I/O paths, two single-port RA4000 Array Controllers are installed in each RA4000 Array or RA4100 Array. Only one array controller can be active at any given time. One array controller is configured as the active controller, and the other is the standby controller. To ensure fault tolerance of shared storage on the RA4000 Array or RA4100 Array, the two array controllers must be connected to a different Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch.

From the perspective of the cluster nodes, each RA4000 Array Controller is simply another device connected to one of the cluster's I/O paths. Consequently, each node sends its I/O requests to the active RA4000 Array Controller just as it would to any SCSI device. The RA4000 Array Controller receives the I/O requests from the nodes and directs them to the shared storage disks to which it has been configured. Because the array controller processes the I/O requests, the cluster nodes are not burdened with the I/O processing tasks associated with reading and writing data to multiple shared storage devices.

When an RA4000/RA4100 Array and the cluster nodes to which it is physically connected are first powered on, the RA4000/RA4100 Array communicates with the nodes to identify which of its two array controller slots contains the active array controller. The array controller that is installed in the active slot is automatically assigned active status by Compaq Secure Path, without the need for any further configuration. To determine which of the two array controllers in an RA4000/RA4100 Array is currently active, find the controller on which the ninth green LED is lit; this LED identifies the active array controller.

To change the active slot location, use Secure Path Manager to make the array controller in the other slot the active controller. For information about configuring the standby array controller to be active, refer to "Defining Active Array Controllers" in Chapter 5, "Installation and Configuration."

If the active RA4000 Array Controller in an RA4000/RA4100 Array fails, Secure Path causes the standby controller to become the active array controller.

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Access to the same logical disks is provided to both RA4000 Array Controllers to allow for successful failovers. In this configuration, both the active and standby array controllers are configured to receive and transmit data for the same logical disks.

For more information about the RA4000 Array Controller, refer to the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.

Fibre Channel SAN Switches

IMPORTANT: For detailed information about cascading two Fibre Channel SAN Switches, refer to the latest Compaq StorageWorks documentation. This guide does not document cascaded configurations for the Fibre Channel SAN Switch.

Fibre Channel SAN Switches are installed between cluster nodes and shared storage subsystems in PDC/O2000 clusters to create redundant Fibre Channel Fabrics.

An 8-port Fibre Channel SAN Switch and 16-port Fibre Channel SAN Switch are supported. From two to four Fibre Channel SAN Switches can be used in each redundant Fibre Channel Fabric.

Fibre Channel SAN Switches are used to connect the Fibre Host Adapters in a PDC/O2000's redundant Fibre Channel Fabric to the array controllers in the RA4000/RA4100 Arrays. Two or more Fibre Channel SAN Switches are used in each redundant Fibre Channel Fabric. Using at least two Fibre Channel SAN Switches provides fault tolerance and supports the redundant architecture described in "Redundant Fibre Channel Fabrics" in this chapter.

Fibre Channel SAN Switches provide full 100 MBps bandwidth on every port. Adding new devices to Fibre Channel SAN Switch ports increases the aggregate bandwidth.

For further information, refer to these manuals provided with each Fibre Channel SAN Switch:

- *Compaq StorageWorks Fibre Channel SAN Switch 8 Installation and Hardware Guide*
- *Compaq StorageWorks Fibre Channel SAN Switch 16 Installation and Hardware Guide*
- *Compaq StorageWorks Fibre Channel SAN Switch Management Guide provided with the Fibre Channel SAN Switch*

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FC-AL Switches

IMPORTANT: For detailed information about cascading two FC-AL Switches, refer to the latest Compaq StorageWorks documentation. This guide does not document cascaded configurations for the FC-AL Switch.

FC-AL Switches can be installed between cluster nodes and shared storage subsystems in PDC/O2000 clusters to create redundant Fibre Channel Arbitrated Loops (FC-ALs).

FC-AL Switches are used to connect the Fibre Host Adapters in a PDC/O2000's redundant FC-AL to the array controllers in the RA4000/RA4100 Arrays. Two or more FC-AL Switches or Storage Hubs are used in each redundant FC-AL. Using at least two FC-AL Switches provides fault tolerance and supports the redundant architecture described in "Redundant Fibre Channel Arbitrated Loops" in this chapter.

The FC-AL Switch 8 supports eight ports. With the addition of the 3-port Expansion Module (PEM), the switch supports 11 ports.

For further information, refer to the *Compaq StorageWorks Fibre Channel Arbitrated Loop Switch (FC-AL Switch) User Guide*.

Storage Hubs

Storage Hubs can also be installed between cluster nodes and shared storage subsystems in PDC/O2000 clusters to create redundant Fibre Channel Arbitrated Loops (FC-ALs).

Storage Hubs are used to connect the Fibre Host Adapters in a PDC/O2000's redundant FC-AL to the array controllers in RA4000/RA4100 Arrays. Two or more Storage Hubs or FC-AL Switches are used in eacb redundant FC-AL. Using at least two Storage Hubs provides fault tolerance and supports the redundant architecture described in "Redundant Fibre Channel Arbitrated Loops" in this chapter.

On each Storage Hub, one port is used by a Fibre Host Adapter in each node and one port is used to connect to one of the two array controllers in each RA4000/RA4100 Array.

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The PDC/O2000 allows the use of either the Storage Hub 7 (with 7 ports) or the Storage Hub 12 (with 12 ports). Using the Storage Hub 7 limits the size of the PDC/O2000 cluster. For example, a cluster with four cluster nodes and four RA4000/RA4100 Arrays requires Storage Hubs with at least 8 ports (Storage Hub 12s). In your selection of Storage Hubs, you should also consider the likelihood of cluster growth.

Refer to the *Compaq StorageWorks Fibre Channel Storage Hub 7 Installation Guide* and the *Compaq StorageWorks Fibre Channel Storage Hub 12 Installation Guide* for further information about the Storage Hubs.

Fibre Host Adapters

Each redundant Fibre Channel Fabric or redundant FC-AL in a PDC/O2000 contains a dedicated set of Fibre Host Adapters in every cluster node. Across servers, Fibre Host Adapters in the same slot are connected to the same Storage Hub, FC-AL Switch, or Fibre Channel Fabric SAN.

If the PDC/O2000 cluster contains multiple redundant Fibre Channel Fabrics or redundant FC-ALs, each redundant Fibre Channel Fabric or redundant FC-AL must have its own dedicated set of Fibre Host Adapters in each cluster node.

Compaq Secure Patb software is installed on each cluster node to ensure the proper detection of failures on an active I/O path and successful failover to the standby I/O path. For information about installing Secure Path, see "Installing Secure Path Software for Windows 2000" in Chapter 5, "Installation and Configuration."

For more information about the Fibre Channel Host Adapter, refer to the *Compaq StorageWorks Fibre Channel Host Bus Adapter Installation Guide* or the *Compaq StorageWorks 64-Bit/66-MHz Fibre Channel Host Adapter Installation Guide*.

Gigabit Interface Converter-Shortwave Modules

A Gigabit Interface Converter-Shortwave (GBIC-SW) module must be installed at both ends of a Fibre Channel cable. A GBIC-SW module is inserted in each Fibre Host Adapter, each active port on a Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch, and each RA4000 Array Controller.

GBIC-SW modules provide 100 MB/second performance. Fibre Channel cables connected to these modules can be up to 500 meters in length.

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Fibre Channel Cables

Shortwave (multi-mode) fibre optic Fibre Channel cables are used to connect the nodes, the Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches, and RA4000/RA4100 Arrays in a PDC/O2000 cluster.

I/O Path Configurations for Redundant Fibre Channel Fabrics

Overview of Fibre Channel Fabric SAN Topology

Fibre Channel standards define a multi-layered architecture for moving data across the storage area network (SAN). This layered architecture can be implemented using the Fibre Channel Fabric or the Fibre Channel Arbitrated Loop (FC-AL) topology. The PDC/O2000 supports both topologies.

A redundant Fibre Channel Fabric is two to four Fibre Channel SAN Switches installed between Fibre Host Adapters in a PDC/O2000's cluster nodes and the array controllers in the shared storage subsystems. These hardware components cannot be shared by other redundant Fibre Channel Fabrics or redundant Fibre Channel Arbitrated Loops in the cluster.

Fibre Channel SAN Switches provide full 100 MBps bandwidth per switch port. Whereas the introduction of new devices to FC-AL Storage Hubs further divides their shared bandwidth, adding new devices to Fibre Channel SAN Switches increases the aggregate bandwidth.

Redundant Fibre Channel Fabrics

A redundant Fibre Channel Fabric refers to the redundant hardware implemented to connect Fibre Host Adapters to a particular set of shared storage devices in a PDC/O2000 that uses Fibre Cbannel SAN Switches. Each redundant Fibre Channel Fabric consists of the following hardware:

- Two or more Fibre Host Adapters in each node
- Two to four Fibre Channel SAN Switches

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- One or more RA4000/RA4100 Arrays, each containing two single-port RA4000 Array Controllers
- GBIC-SW modules installed in the Fibre Host Adapters, Fibre Channel SAN Switches, and array controllers
- Fibre Channel cables used to connect the Fibre Host Adapters to the Fibre Channel SAN Switches and the Fibre Channel SAN Switches to the array controllers

IMPORTANT: For detailed information about cascading two Fibre Channel SAN Switches, refer to the latest Compaq StorageWorks documentation. This guide does not document cascaded configurations for the Fibre Channel SAN Switch.

A redundant Fibre Channel Fabric consists of from two to four individual fabrics, each of which traverses a single Fibre Channel SAN Switch. The number of fabrics present is determined by the number of Fibre Host Adapters per node that are dedicated to the redundant Fibre Channel Fabric: two Fibre Host Adapters per node create two fabrics; four Fibre Host Adapters per node create four fabrics.

Figure 2-1 shows a two-node PDC/O2000 with a redundant Fibre Channel Fabric that contains two fabrics, one for each Fibre Host Adapter per node. The components and cable paths for the first fabric are shaded to distinguish them from the components and cables for the second fabric.

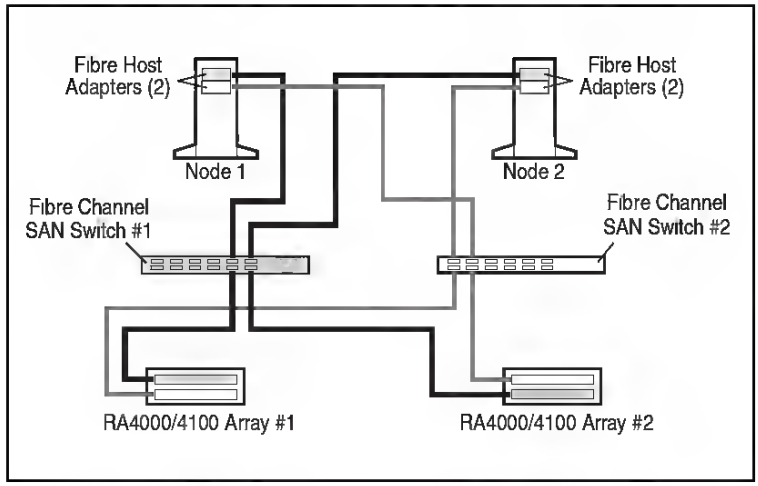

Figure 2-1. Two-node PDC/O2000 with a two-fabric redundant Fibre Channel Fabric

Used in conjunction with the I/O path failover capabilities of Secure Path software, this redundant Fibre Channel Fabric configuration gives cluster resources increased availability and fault tolerance.

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Multiple Redundant Fibre Channel Fabrics

The PDC/O2000 supports the use of multiple redundant Fibre Channel Fabrics within the same cluster. You would install additional redundant Fibre Channel Fabrics in a PDC/O2000 to:

- Increase the amount of shared storage space available to the cluster's nodes. Each redundant Fibre Channel Fabric can connect to a finite number of RA4000/RA4100 Arrays. These RA4000/RA4100 Arrays are available only to the Fibre Host Adapters connected to that redundant Fibre Channel Fabric.
- Increase the cluster's I/O performance.

Adding a second redundant Fibre Channel Fabric to the cluster involves duplicating the hardware components used in the first redundant Fibre Channel Fabric.

The maximum number of redundant Fibre Channel Fabrics you can install in a PDC/O2000 cluster is restricted by the number of Fibre Host Adapters your Compaq servers support. Refer to the Compaq server documentation for this information.

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Figure 2-2 shows a two-node PDC/O2000 that contains two redundant Fibre Channel Fabrics. In this example, each redundant Fibre Channel Fabric has its own pair of Fibre Host Adapters in each node, a pair of Fibre Channel SAN Switches, and two RA4000/RA4100 Arrays. In Figure 2-2, the hardware components that constitute the second redundant Fibre Channel Fabric are shaded.

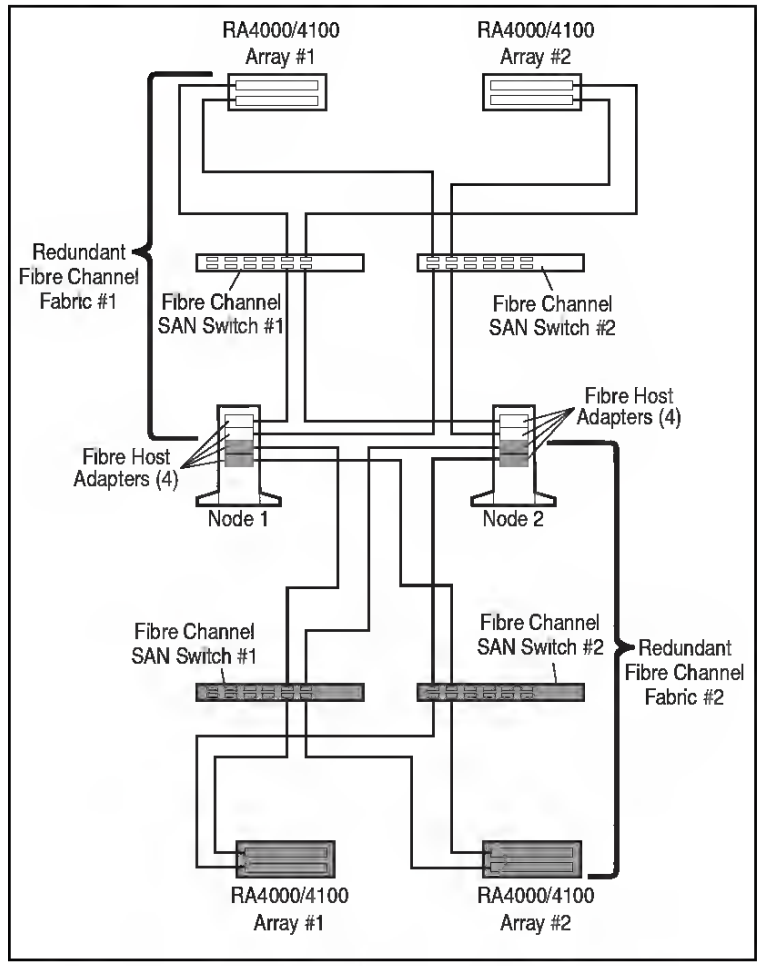

Figure 2-2. Two-node PDC/O2000 with two redundant Fibre Channel Fabrics

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Maximum Distances Between Nodes and Shared Storage Components in a Redundant Fibre Channel Fabric

By using standard short-wave Fibre Channel cables with Gigabit Interface Converter-Shortwave (GBIC-SW) modules, the following maximum distances apply:

- Each RA4000/RA4100 Array can be placed up to 500 meters from the Fibre Channel SAN Switches to which it is cabled.
- Each Fibre Channel SAN Switch can be placed up to 500 meters from the Fibre Host Adapters to which it is cabled.

Figure 2-3 illustrates these maximum cable distances for a redundant Fibre Channel Fabric.

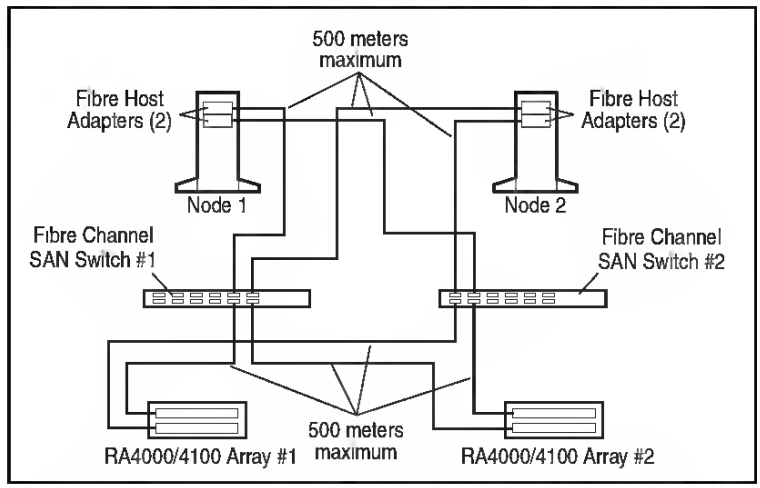

Figure 2-3. Maximum distances between PDC/O2000 cluster nodes and shared storage subsystem components in a redundant Fibre Channel Fabric

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I/O Data Paths in a Redundant Fibre Channel Fabric

A distinct I/O path connection exists between each Fibre Host Adapter in a redundant Fibre Channel Fabric and every array controller port in each RA4000/RA4100 Array in that redundant Fibre Channel Fabric.

Fibre Host Adapter-to-Fibre Channel SAN Switch Paths

Figure 2-4 highlights the I/O data paths that run between the Fibre Host Adapters and the Fibre Channel SAN Switches in a redundant Fibre Channel Fabric.

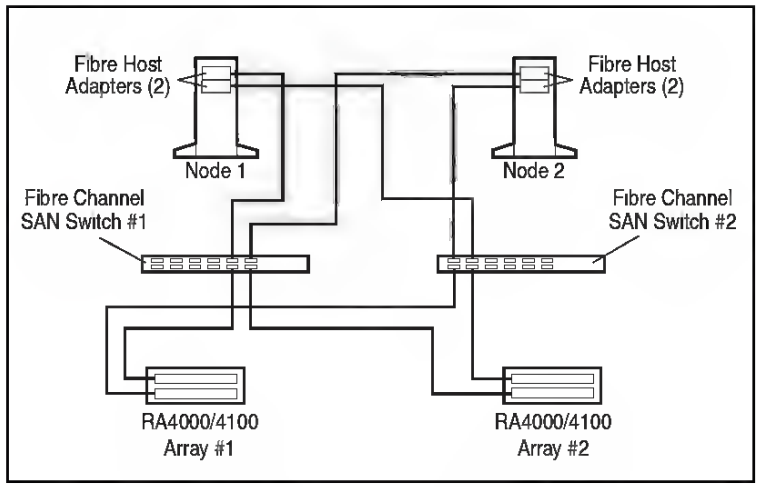

Figure 2-4. Fibre Host Adapter-to-Fibre Channel SAN Switch data paths

Secure Path monitors the status of the components along each active path. If Secure Path detects the failure of a Fibre Host Adapter, Fibre Channel cable, or Fibre Channel SAN Switch along an active path, it automatically transfers all I/O activity on that path to the components on the defined backup path.

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Fibre Channel SAN Switch-to-Array Controller Paths

Figure 2-5 highlights the I/O data paths that run between the Fibre Cbannel SAN Switches and the two single-port RA4000 Array Controllers in each RA4000/RA4100 Array.

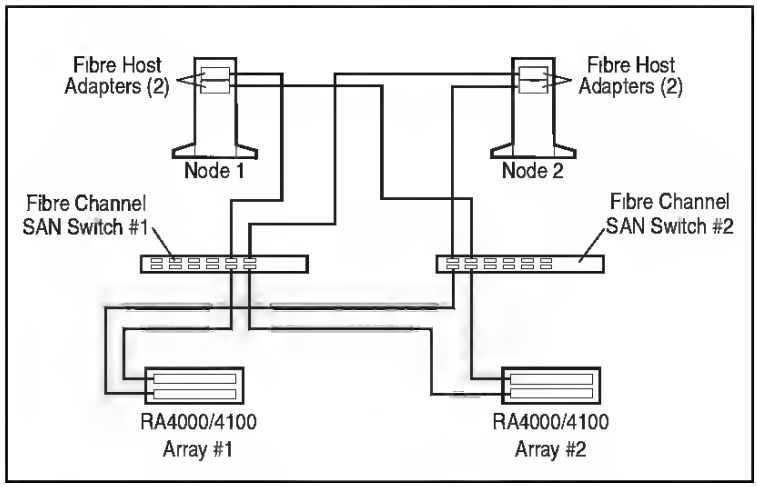

Figure 2-5. Fibre Channel SAN Switch-to-RA4100/4000 Array data paths

If any component along an active path fails, Secure Path detects the failure and automatically transfers all I/O activity to the components on the defined backup path.

I/O Path Configuration Guidelines for Redundant Fibre Channel Fabrics

You can use either of two I/O path configurations for every redundant FC-AL in your PDC/O2000 cluster:

- Active/standby configuration
- Active/active configuration

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In every redundant Fibre Channel Fabric, at least two Fibre Host Adapters must be installed in each node (one adapter for each Fibre Channel SAN Switch in that redundant Fibre Channel Fabric).

In the active/standby configuration, only one of the two Fibre Host Adapters in each node is active at any one time; the other Fibre Host Adapter is in the standby state. The active Fibre Host Adapter is connected to the first Fibre Channel SAN Switch, which is connected to the active array controller in each RA4000/RA4100 Array. The standby Fibre Host Adapter is connected to the second Fibre Channel SAN Switch, which is connected to the standby array controller in each RA4000/RA4100 Array. The standby Fibre Host Adapter remains in the standby state unless a failover from the active I/O path occurs. In the active/standby configuration, the failure of any component along an active I/O path (Fibre Host Adapter, Fibre Channel SAN Switcb, active array controller, or Fibre Channel cable) causes Secure Path to implement a complete failover to the components on the standby I/O path.

In the active/active configuration, both Fibre Host Adapters in each node are simultaneously active. Both are active because each Fibre Host Adapter is connected to a Fibre Channel SAN Switch that, in turn, is connected to an active array controller in each RA4000/RA4100 Array. Because each Fibre Host Adapter and Fibre Channel SAN Switch must connect to at least one active array controller, at least two RA4000/RA4100 Arrays must be present in an active/active configuration.

See "Active/Standby Configuration Examples for Redundant Fibre Channel Fabrics" in this chapter for a detailed description of active/standby configuration examples with from one to five RA4000/RA4100 Arrays. See "Active/Active Configuration Examples for Redundant Fibre Channel Fabrics" for a detailed description of active/active configuration examples when two to five RA4000/RA4100 Arrays are present.

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Table 2-2 identifies the features of the active/standby and active/active configurations for redundant Fibre Channel Fabrics.

Table 2-2
Features of Active/Standby and Active/Active Configurations for Redundant Fibre Channel Fabrics

I/O Path Configuration	Advantage	Disadvantage
Active/standby with one RA4000/RA4100 Array	Active/standby is the only I/O path configuration you can use in a redundant Fibre Channel Fabric that contains just one RA4000/RA4100 Array.	
Active/standby with two or more RA4000/RA4100 Arrays	Provides true cabling symmetry between the Fibre Channel SAN Switches and array controllers. A Fibre Channel SAN Switch connects to the same array controller slot (top or bottom) in every RA4000/RA4100 Array.	Load balancing between the two Fibre Channel SAN Switches is less than ideal because the connection to the active array controller in every RA4000/RA4100 Array is routed through the same Fibre Channel SAN Switch. The second Fibre Channel SAN Switch provides no active I/O pathway unless an active array controller or its cable connection to the first Fibre Channel SAN Switch fails.

continued

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Table 2-2
Features of Active/Standby and Active/Active Configurations for Redundant Fibre Channel Fabrics *continued*

I/O Path Configuration	Advantage	Disadvantage
Active/active with two or more RA4000/RA4100 Arrays	Provides a small but measurable improvement in I/O performance over the active/standby configuration because both Fibre Host Adapters in each node and both Fibre Channel SAN Switches are simultaneously active. This improvement can be meaningful for customers with large cluster databases or high I/O transaction requirements. Provides better load balancing between the two Storage Hubs than the active/standby configuration. Both Fibre Channel SAN Switches are connected to the same or equivalent numbers of both active and standby array controllers in the RA4000/RA4100 Arrays.	Does not provide true cabling symmetry between Fibre Channel SAN Switches and array controllers if you consistently configure the top or rightmost array controller as the active controller. Each Fibre Channel SAN Switch is cabled to top (active) array controllers in some RA4000/RA4100 Arrays and bottom (standby) controllers in others. You can achieve cabling symmetry if you configure the bottom array controller in some RA4000/RA4100 Arrays as active. However, this requires using Secure Path to configure the lower array controller as active if it is in standby mode.

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I/O Path Configuration Rules for Redundant Fibre Channel Fabrics

The following rules must be observed in I/O path configurations for PDC/O2000 clusters with redundant Fibre Channel Fabrics:

- Each redundant Fibre Channel Fabric must use either an active/standby or active/active configuration. The active/standby or active/active configuration is confined to that redundant Fibre Channel Fabric.
- For each redundant Fibre Channel Fabric, at least two Fibre Host Adapters are installed in each cluster node (one for each Fibre Channel SAN Switch).
- For each redundant Fibre Channel Fabric, at least two Fibre Channel SAN Switches (Fibre Channel SAN Switch #1 and Fibre Channel SAN Switch #2) are installed between the nodes and the RA4000/RA4100 Arrays.
- A minimum of one RA4000/RA4100 Array is required for the active/standby configuration.
- A minimum of two RA4000/RA4100 Arrays is required for the active/active configuration.
- Each RA4000/RA4100 Array must contain two array controllers to provide redundant paths.
- Only one of the two array controllers in an RA4000/RA4100 Array can be active at a given time. The other array controller is the standby controller.
- I/O path hardware components must be connected using Fibre Channel cables and GBIC-SW modules.

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Active/Standby Configuration Examples for Redundant Fibre Channel Fabrics

This section describes examples of active/standby configurations when one, two, three, four, and five RA4000/RA4100 Arrays are present in one redundant Fibre Channel Fabric of a four-node PDC/O2000. These examples represent one method for configuring active/standby configurations. They are presented here to provide a relatively simple and consistent method for building active/standby configurations for redundant Fibre Channel Fabrics.

IMPORTANT: Figures 2-6 through 2-10 show active/standby configurations for a four-node cluster. Active/standby configurations for clusters with two, three, five, or more nodes are not described here. However, the illustrated active/standby configuration examples provided should supply sufficient information for building an active/standby configuration in any PDC/O2000 cluster.

The active/standby configuration examples shown in Figures 2-6 through 2-10 follow these configuration guidelines:

- For every Fibre Host Adapter pair, the top or leftmost Fibre Host Adapter in each node is connected to the odd-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #1). This is the active Fibre Host Adapter in the pair.
- For every Fibre Host Adapter pair, the bottom or rightmost Fibre Host Adapter in each node is connected to the even-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #2). This is the standby Fibre Host Adapter in the pair.
- In each RA4000/RA4100 Array, the top (rack model) or right rear (tower model) array controller is always the active controller.

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- In each RA4000/RA4100 Array, the bottom (rack model) or left rear (tower model) array controller is always the standby controller.
- The odd-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #1) is connected to the active array controller in eacb RA4000/RA4100 Array.
- The even-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #2) is connected to the standby array controller in each RA4000/RA4100 Array.

NOTE: The following active/standby configurations are examples only. You are not required to follow these configurations.

For more information about installing active/standby configurations, refer to the following sections in Chapter 5, "Installation and Configuration":

- "Cabling the Fibre Host Adapters to the Storage Hubs or Switches"
- "Cabling the Storage Hubs or Switches to the RA4000 Array Controllers"

In Figures 2-6 through 2-10, active I/O path components have been shaded to distinguish them from standby (inactive) components. Black Fibre Channel cables identify connections between active components; gray cables identify connections between standby components.

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Active/Standby Configuration with One RA4000/4100 Array

Figure 2-6 shows an active/standby I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with one RA4000/RA4100 Array.

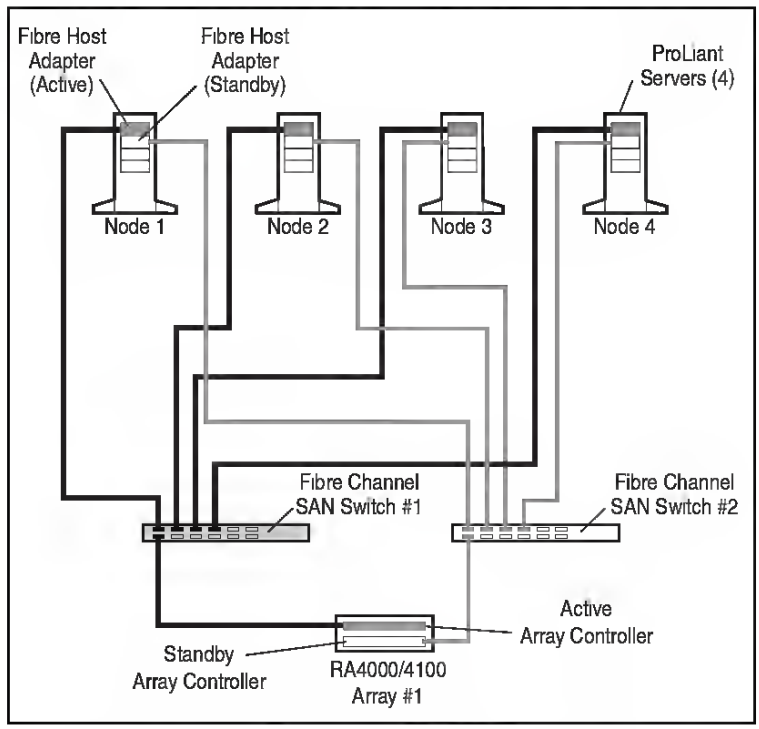

Figure 2-6. Active/standby configuration with one RA4000/RA4100 Array

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Active/Standby Configuration with Two RA4000/4100 Arrays

Figure 2-7 shows an active/standby I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with two RA4000/RA4100 Arrays.

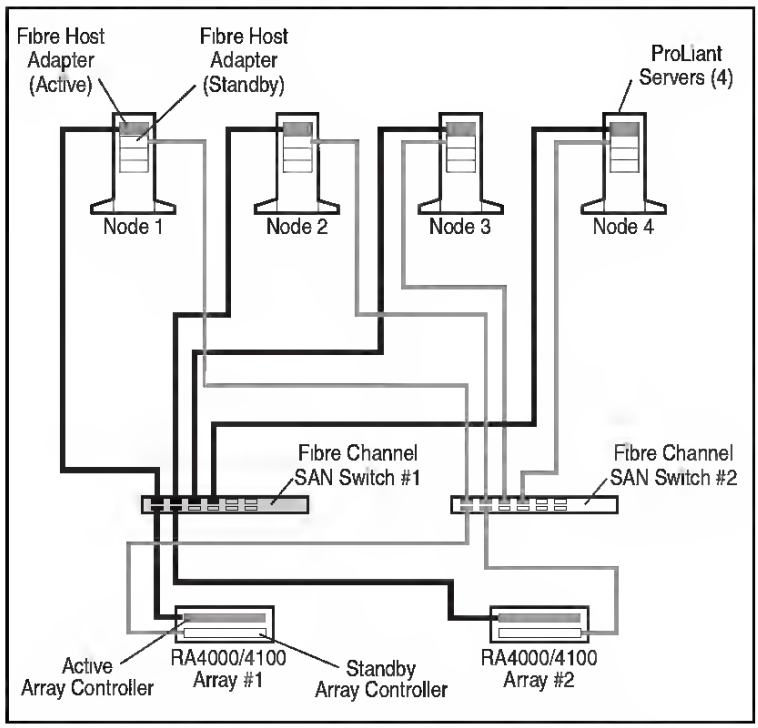

Figure 2-7. Active/standby configuration with two RA4000/RA4100 Arrays

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Active/Standby Configuration with Three RA4000/RA4100 Arrays

Figure 2-8 shows an active/standby I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with three RA4000/RA4100 Arrays.

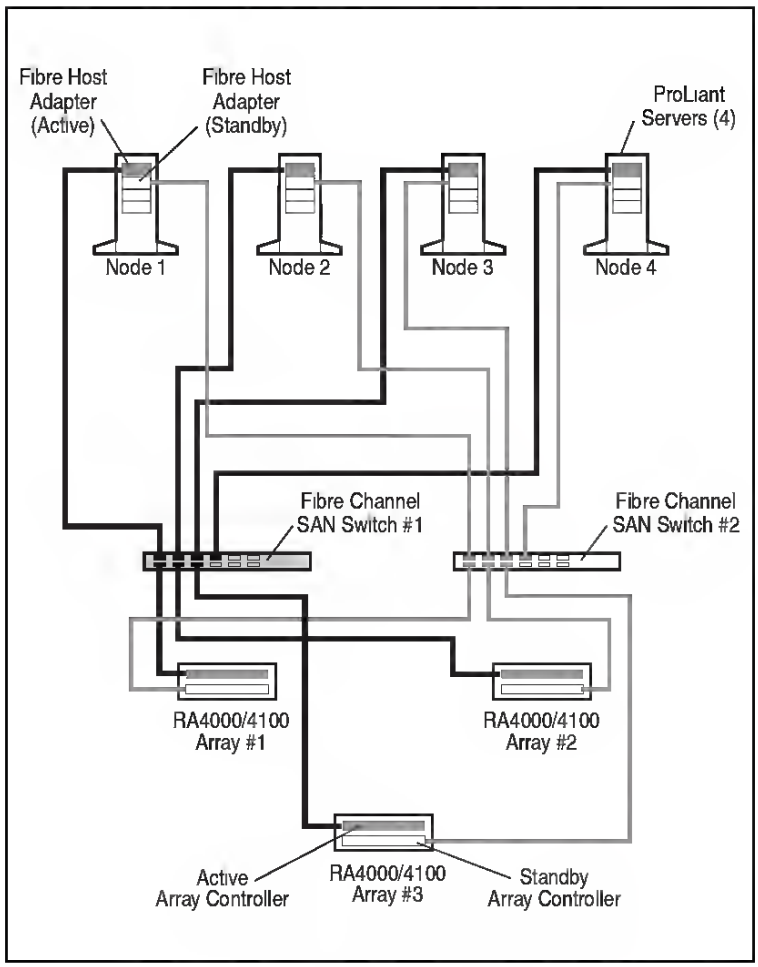

Figure 2-8. Active/standby configuration with three RA4000/RA4100 Arrays

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Active/Standby Configuration with Four RA4000/RA4100 Arrays

Figure 2-9 shows an active/standby I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with four RA4000/RA4100 Arrays.

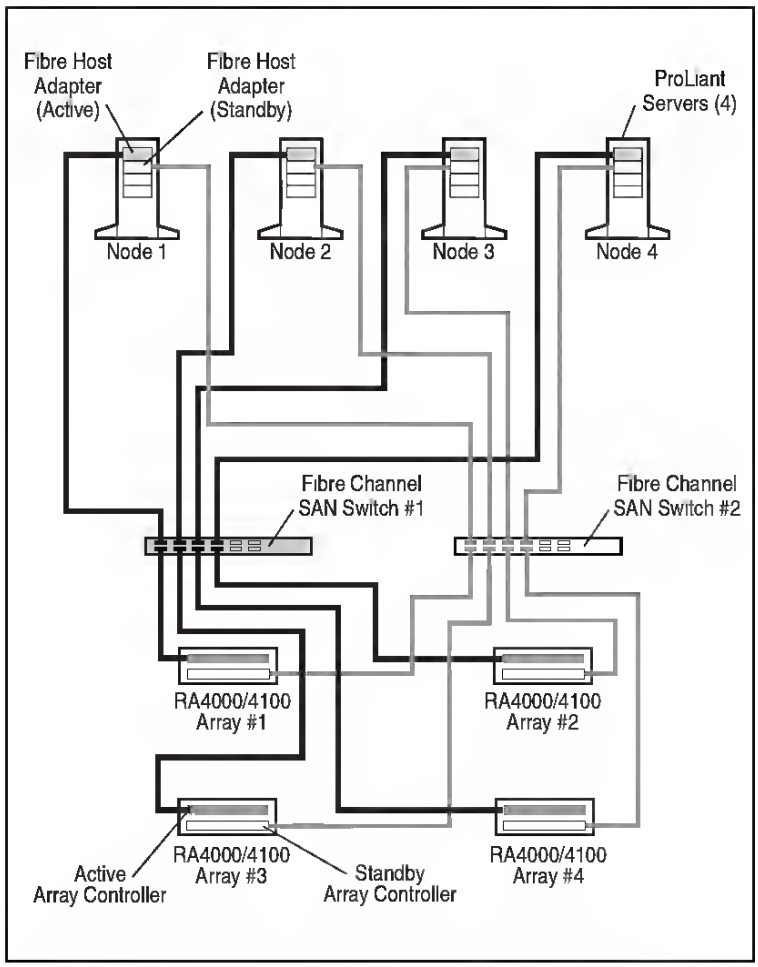

Figure 2-9. Active/standby configuration with four RA4000/RA4100 Arrays

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Active/Standby Configuration with Five RA4000/RA4100 Arrays

Figure 2-10 shows an active/standby I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with five RA4000/RA4100 Arrays.

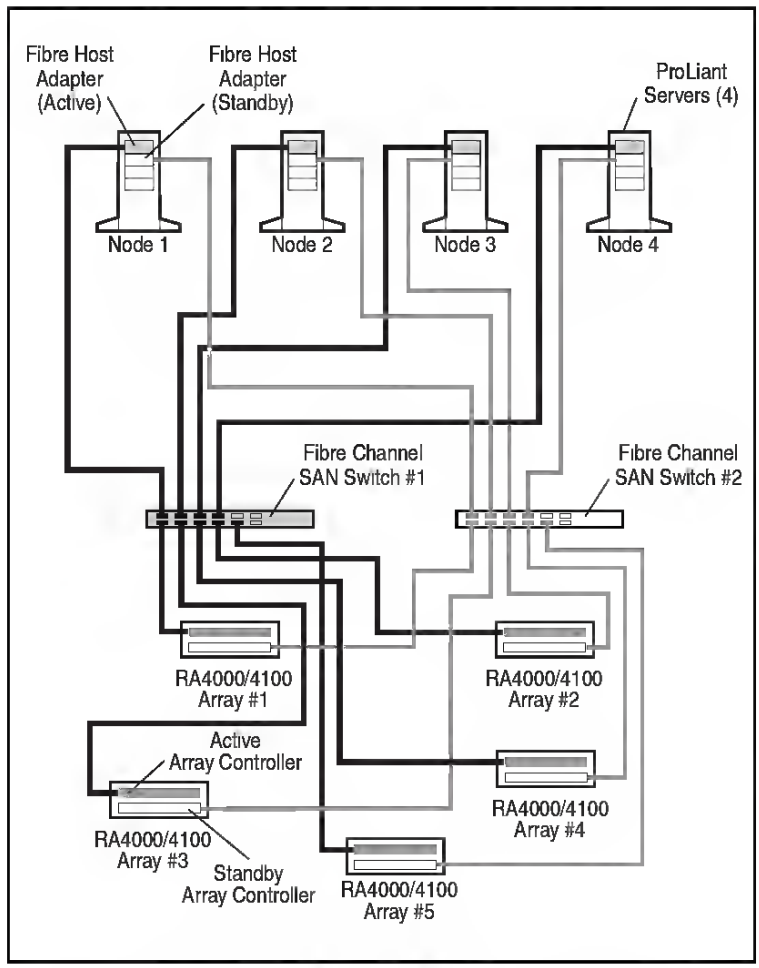

Figure 2-10. Active/standby configuration with five RA4000/RA4100 Arrays

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Active/Active Configuration Examples for Redundant Fibre Channel Fabrics

This section describes examples of active/active configurations when two, three, four, and five RA4000/RA4100 Arrays are present in one redundant Fibre Channel Fabric of a four-node PDC/O2000 cluster. These examples represent one method for configuring active/active configurations. They are presented here to provide a relatively simple and consistent method for building active/active configurations for redundant Fibre Channel Fabrics.

IMPORTANT: Figures 2-11 through 2-14 show active/active configurations for a four-node cluster. Active/active configurations for clusters with two, three, five, or more nodes are not described here. However, the illustrated active/active configuration examples provided should supply sufficient information for building an active/standby configuration in any PDC/O2000 cluster.

The active/active configuration examples shown in Figures 2-11 through 2-14 follow these configuration guidelines:

- For every Fibre Host Adapter pair, the top or leftmost Fibre Host Adapter in each node is connected to the odd-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #1). This is an active Fibre Host Adapter.
- For every Fibre Host Adapter pair, the bottom or rightmost Fibre Host Adapter in each node is connected to the even-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #2). This is also an active Fibre Host Adapter.
- In each RA4000/RA4100 Array, the top (rack model) or right rear (tower model) array controller is always the active controller.
- In each RA4000/RA4100 Array, the bottom (rack model) or left rear (tower model) array controller is always the standby controller.
- The odd-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #1) is connected to the active array controller in each odd-numbered RA4000/RA4100 Array (1, 3, and 5).
- The odd-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #2) is connected to the standby array controller in each even-numbered RA4000/RA4100 Array (2 and 4).

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- The even-numbered Fibre Channel SAN Switch (Fibre Channel SAN Switch #2) is connected to the active array controller in each even-numbered RA4000/RA4100 Array (2 and 4).
- The even-numbered Fibre Channel SAN Switch is connected to the standby array controller in each odd-numbered RA4000/RA4100 Array (1, 3, and 5).

NOTE: The following active/active configurations are examples only. You are not required to follow these configurations.

For more information about installing active/active configurations, refer to these sections in Chapter 5, "Installation and Configuration":

- Cabling the Fibre Host Adapters to the Storage Hubs or Switches
- Cabling the Storage Hubs or Switches to the RA4000 Array Controllers

In Figures 2-11 through 2-14, active I/O path components have been shaded to distinguish them from standby (inactive) components. Black Fibre Channel cables identify connections between active components; gray cables identify connections between standby components.

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Active/Active Configuration with Two RA4000/RA4100 Arrays

Figure 2-11 shows an active/active I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with two RA4000/RA4100 Arrays.

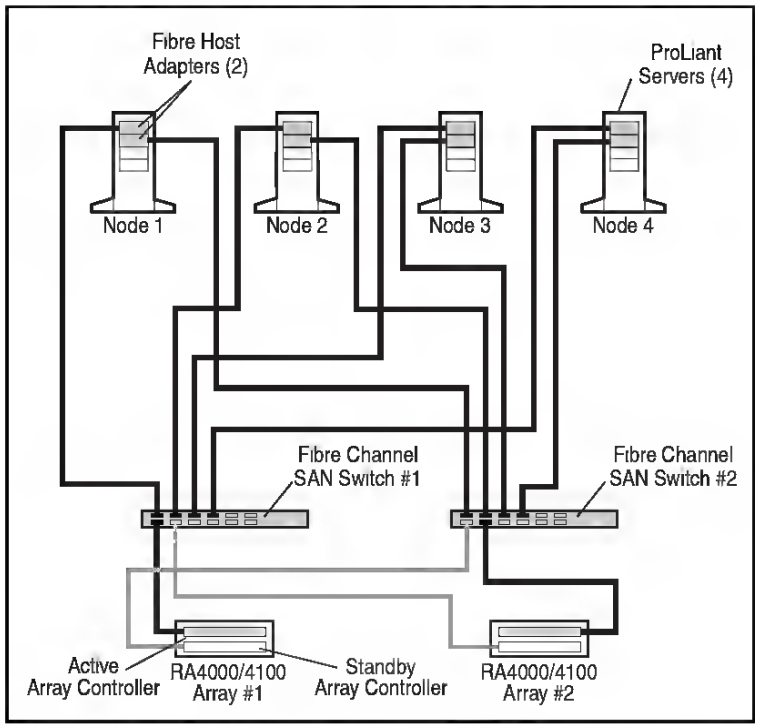

Figure 2-11. Active/active configuration with two RA4000/RA4100 Arrays

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Active/Active Configuration with Three RA4000/RA4100 Arrays

Figure 2-12 shows an active/active I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with three RA4000/RA4100 Arrays.

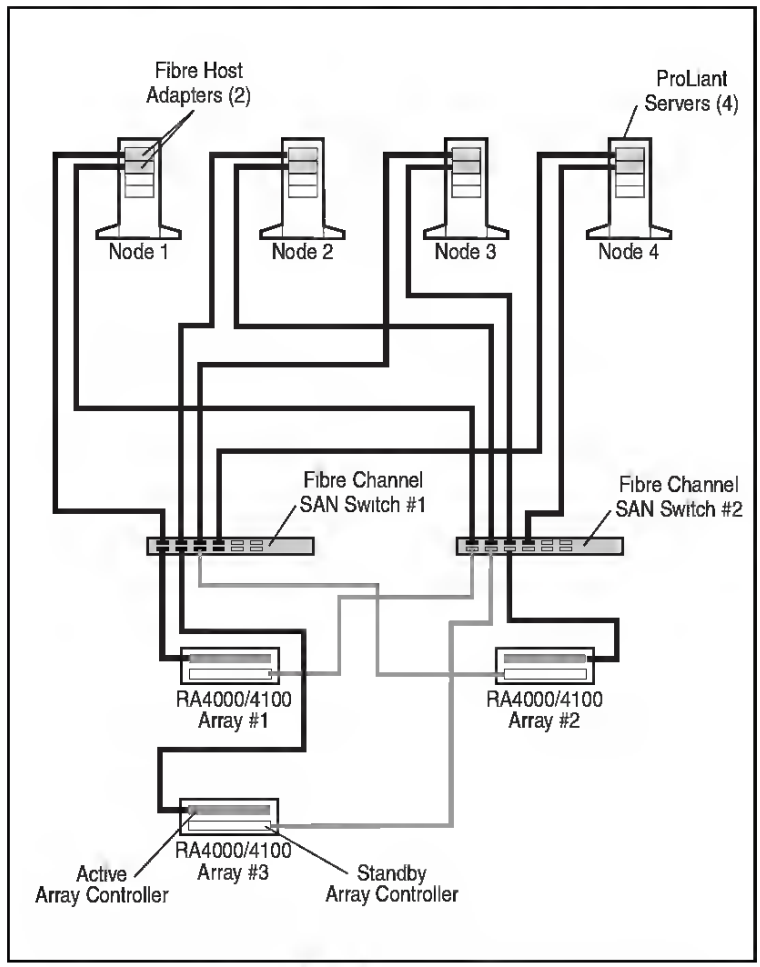

Figure 2-12. Active/active configuration with three RA4000/RA4100 Arrays

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Active/Active Configuration with Four RA4000/RA4100 Arrays

Figure 2-13 shows an active/active I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with four RA4000/RA4100 Arrays.

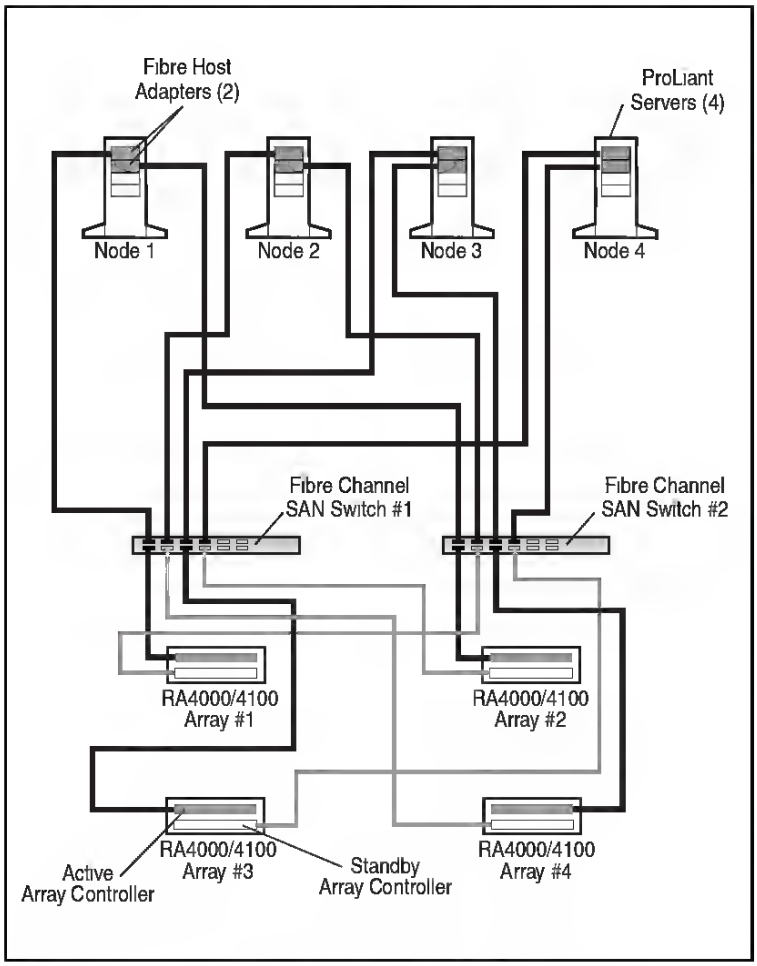

Figure 2-13. Active/active configuration with four RA4000/RA4100 Arrays

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Active/Active Configuration with Five RA4000/RA4100 Arrays

Figure 2-14 shows an active/active I/O path configuration for a redundant Fibre Channel Fabric in a four-node cluster with five RA4000/RA4100 Arrays.

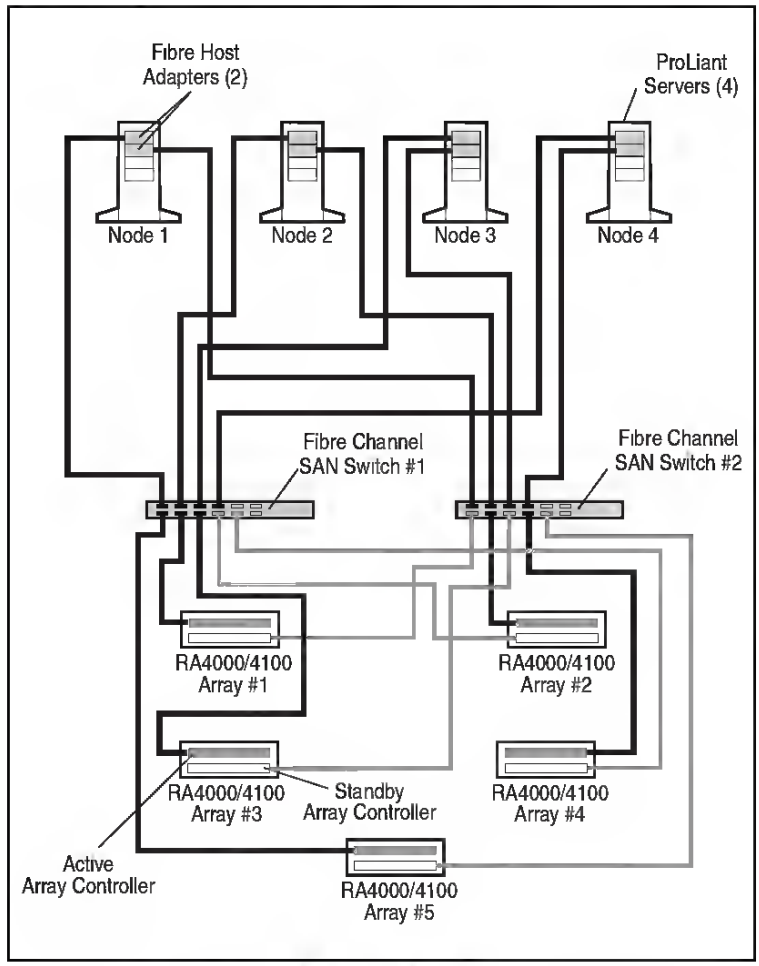

Figure 2-14. Active/active configuration with five RA4000/RA4100 Arrays

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Summary of I/O Path Failure and Failover Scenarios for Redundant Fibre Channel Fabrics

Table 2-3 identifies possible I/O path failure events in redundant Fibre Channel Fabrics for active/standby configurations with one RA4000/RA4100 Array and the failover response, if any, implemented by Secure Path for each failure.

Table 2-3
I/O Path Failure and Failover Scenarios in Redundant Fibre Channel Fabrics for Active/Standby Configurations With One RA4000/RA4100 Array

Description of Failure	Failover Response
The active array controller in the RA4000/RA4100 Array fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
The standby array controller in the RA4000/RA4100 Array fails.	None
The Fibre Channel cable connection between the active array controller and its Fibre Channel SAN Switch is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
The Fibre Channel cable connection between the standby array controller and its Fibre Channel SAN Switch is broken.	None
The Fibre Channel SAN Switch connected to the active array controller fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.

continued

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Table 2-3
I/O Path Failure and Failover Scenarios in Redundant Fibre Channel Fabrics for Active/Standby Configurations With One RA4000/RA4100 Array *continued*

Description of Failure	Failover Response
The Fibre Channel SAN Switch connected to the standby array controller fails.	None
The Fibre Channel cable connection between a Fibre Host Adapter and the Fibre Channel SAN Switch connected to the active array controller is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
The Fibre Channel cable connection between a Fibre Host Adapter and the Fibre Channel SAN Switch connected to the standby array controller is broken.	None
A Fibre Host Adapter connected to the Fibre Channel SAN Switch that connects to the active array controller fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
A Fibre Host Adapter connected to the Fibre Channel SAN Switch that connects to the standby array controller fails.	None

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Table 2-4 identifies possible I/O path failure events for active/standby configurations in redundant Fibre Channel Fabrics with two or more RA4000/RA4100 Arrays and the failover response, if any, implemented by Secure Path for each failure.

Table 2-4
I/O Path Failure and Failover Scenarios in Redundant Fibre Channel Fabrics for Active/Standby Configurations With Two or More RA4000/RA4100 Arrays

Description of Failure	Failover Response
The active array controller in one RA4000/RA4100 Array fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.
The standby array controller in one RA4000/RA4100 Array fails.	None
The Fibre Channel cable connection between the active array controller in one RA4000/RA4100 Array and its Fibre Channel SAN Switch is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.

continued

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Table 2-4
I/O Path Failure and Failover Scenarios in Redundant Fibre Channel Fabrics for Active/Standby Configurations With Two or More RA4000/RA4100 Arrays *continued*

Description of Failure	Failover Response
The Fibre Channel cable connection between the standby array controller in one RA4000/RA4100 Array and its Fibre Channel SAN Switch is broken.	None
The Fibre Channel SAN Switch that is connected to the active array controller in each RA4000/RA4100 Array fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.
The Fibre Channel SAN Switch that is connected to the standby array controller in each RA4000/RA4100 Array fails.	None
The Fibre Channel cable connection between the Fibre Channel SAN Switch that is connected to the active array controllers and a Fibre Host Adapter is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in the each RA4000/RA4100 Array, and Fibre Channel cables.
The Fibre Channel cable connection between the Fibre Channel SAN Switch that is connected to the standby array controllers and a Fibre Host Adapter is broken.	None
A Fibre Host Adapter connected to the Fibre Channel SAN Switch that is connected to the active array controllers fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Fibre Channel SAN Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.
A Fibre Host Adapter connected to the Fibre Channel SAN Switch that is connected to the standby array controllers fails.	None

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Table 2-5 identifies possible I/O path failure events in redundant Fibre Channel Fabrics for active/active configurations with two or more RA4000/RA4100 Arrays and the failover response, if any, implemented by Secure Path for each failure.

Table 2-5
I/O Path Failure and Failover Scenarios in Redundant Fibre Channel Fabrics for Active/Active Configurations With Two or More RA4000/RA4100 Arrays

Description of Failure	Failover Response
The active array controller in one RA4000/RA4100 Array fails.	Secure Path makes the standby array controller in the RA4000/RA4100 Array active and reroutes I/O activity to that array controller. The Fibre Channel SAN Switch that is connected to the new active array controller becomes the active I/O path to this RA4000/RA4100 Array. In each node, I/O activity between the Fibre Host Adapter that is connected to the failed array controller is rerouted to the second Fibre Host Adapter in the pair, but only along the I/O path to the affected RA4000/RA4100 Array. The first Fibre Host Adapter in each node continues to be the active I/O path for active array controllers in other RA4000/RA4100 Arrays to which it is connected.
The standby array controller in one RA4000/RA4100 Array fails.	None
The Fibre Channel cable connection between the active array controller in one RA4000/RA4100 Array and its Fibre Channel SAN Switch is broken.	Secure Path makes the active array controller to which the failed cable is connected inactive. The standby array controller in the RA4000/RA4100 Array becomes active. I/O activity is routed through the Fibre Channel cable installed to the new active array controller and the other Fibre Channel SAN Switch. In each node, I/O activity between the Fibre Host Adapter that is connected to the failed array controller is rerouted to the second Fibre Host Adapter in the pair, but only along the I/O path to the affected RA4000/RA4100 Array. The first Fibre Host Adapter in each node continues to be the active I/O path for active array controllers in other RA4000/RA4100 Arrays to which it is connected.

continued

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Table 2-5
I/O Path Failure and Failover Scenarios in Redundant Fibre Channel Fabrics for Active/Active Configurations With Two or More RA4000/RA4100 Arrays *continued*

Description of Failure	Failover Response
The Fibre Channel cable connection between the standby array controller in one RA4000/RA4100 Array and its Fibre Channel SAN Switch is broken.	None
A Fibre Channel SAN Switch fails.	Secure Path makes each active array controller to which the failed Fibre Channel SAN Switch is connected inactive. The standby array controller in each affected RA4000/RA4100 Array becomes the active array controller. The Fibre Channel SAN Switch that is connected to the new active array controllers becomes the active I/O path for these RA4000/RA4100 Arrays. In each node, the Fibre Host Adapter that is connected to the failed Fibre Channel SAN Switch becomes inactive, and all I/O activity is rerouted through the other Fibre Host Adapter in the pair and the remaining active Fibre Channel SAN Switch.
The Fibre Channel cable connection between a Fibre Channel SAN Switch and a Fibre Host Adapter in one node is broken.	Secure Path makes all I/O path connections between the affected Fibre Host Adapter and active array controllers inactive. The standby array controller in every affected RA4000/RA4100 Array becomes the active array controller. The Fibre Channel SAN Switch connected to the newly active array controllers becomes the active I/O path for the entire FC-AL. The Fibre Channel SAN Switch connected to the failed Fibre Channel cable becomes inactive. The second Fibre Host Adapter in each node, which is connected to the only active Fibre Channel SAN Switch, becomes the only active Fibre Host Adapter in the node's pair.
A Fibre Host Adapter in a node fails.	Secure Path makes all I/O path connections between the affected Fibre Host Adapter and active array controllers inactive. The standby array controller in every affected RA4000/RA4100 Array becomes the active array controller. The Fibre Channel SAN Switch connected to the newly active array controllers becomes the active I/O path for the entire FC-AL. The Fibre Channel SAN Switch connected to the failed Fibre Host Adapter becomes inactive. The second Fibre Host Adapter in each node, which is connected to the only active Fibre Channel SAN Switch, becomes the only active Fibre Host Adapter in the node's pair.

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I/O Path Configurations for Redundant Fibre Channel Arbitrated Loops

Overview of FC-AL SAN Topology

Fibre Channel standards define a multi-layered architecture for moving data across the storage area network (SAN). This layered architecture can be implemented using the Fibre Channel Fabric or the Fibre Channel Arbitrated Loop (FC-AL) topology. The PDC/O2000 supports both topologies.

A redundant FC-AL is two to four FC-AL Switches or Storage Hubs installed between Fibre Host Adapters in a PDC/O2000's cluster nodes and the array controllers in the shared storage subsystems. These hardware components cannot be shared by other redundant FC-ALs or redundant Fibre Channel Fabrics in the same cluster.

When Storage Hubs are used, the FC-AL SAN is a shared gigabit transport with a total 100 MBps bandwidth divided among all Storage Hub ports. The functional bandwidth available to any one device on a Storage Hub port is determined by the total population on the segment and the level of activity of devices on other ports. The more devices used, the less bandwidth that is available for each port.

When FC-AL Switches are used, the FC-AL SAN supports multiple 100 MB/sec point-to-point connections in parallel. Each FC-AL Switch provides multiple dedicated, non-blocking connections between Fibre Host Adapters and array controllers (as contrasted with the shared connections on a Storage Hub). The FC-AL Switch also eliminates the shared bandwidth speed limitations of the Storage Hub.

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Redundant Fibre Channel Arbitrated Loops

A redundant FC-AL refers to the redundant hardware implemented to connect Fibre Host Adapters to a particular set of shared storage devices in a PDC/O2000. Each redundant FC-AL consists of the following hardware:

- Two or more Fibre Host Adapters in each node
- Two or more Storage Hubs or FC-AL Switches
- One or more RA4000/RA4100 Arrays, each containing two single-port RA4000 Array Controllers
- GBIC-SW modules installed in Fibre Host Adapters, Storage Hubs or FC-AL Switches, and array controllers to connect Fibre Channel cables
- Fibre Channel cables used to connect the Fibre Host Adapters to the Storage Hubs or FC-AL Switches to the array controllers

IMPORTANT: For detailed information about cascading two FC-AL Switches, refer to the latest Compaq StorageWorks documentation. This guide does not document cascaded configurations for the FC-AL Switch.

A redundant FC-AL consists of from two to four individual loops, each of which traverses a single Storage Hub or FC-AL Switch. The number of loops present is determined by the number of Fibre Host Adapters per node that are dedicated to the redundant FC-AL: two Fibre Host Adapters per node create two loops; four Fibre Host Adapters per node create four loops.

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Figure 2-15 shows a two-node PDC/O2000 with a redundant FC-AL that contains two loops, one for each Fibre Host Adapter per node. The components and cable paths for the first loop are shaded to distinguish them from the components for the other loop.

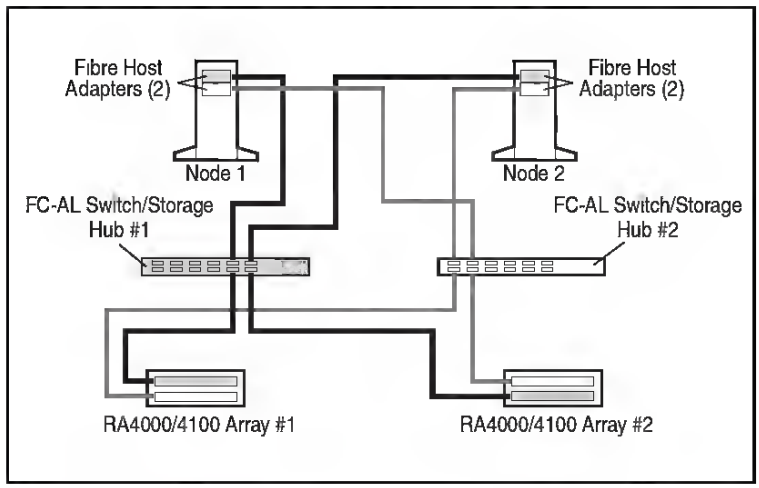

Figure 2-15. Two-node PDC/O2000 with a two-loop redundant Fibre Channel Arbitrated Loop

Used in conjunction with the I/O path failover capabilities of Secure Path software, this redundant FC-AL configuration gives cluster resources increased availability and fault tolerance.

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Multiple Redundant Fibre Channel Arbitrated Loops

The PDC/O2000 supports the use of multiple redundant FC-ALs within the same cluster. You would install additional redundant FC-ALs in a PDC/O2000 to:

- Increase the amount of shared storage space available to the cluster's nodes. Each redundant FC-AL can connect to a finite number of RA4000/RA4100 Arrays. These RA4000/RA4100 Arrays are available only to the Fibre Host Adapters connected to that redundant FC-AL.
- Increase the cluster's I/O performance.

Adding a second redundant FC-AL to the cluster involves duplicating the hardware components used in the first redundant FC-AL.

The maximum number of redundant FC-ALs you can install in a PDC/O2000 cluster is restricted by the number of Fibre Host Adapters your Compaq servers support. Refer to the Compaq server documentation for this information.

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Figure 2-16 shows a two-node PDC/O2000 that contains two redundant FC-ALs. In this example, each redundant FC-AL has its own pair of Fibre Host Adapters in each node, a pair of Storage Hubs or FC-AL Switches, and two RA4000/RA4100 Arrays. In Figure 2-2, the hardware components that constitute the second redundant FC-AL are shaded.

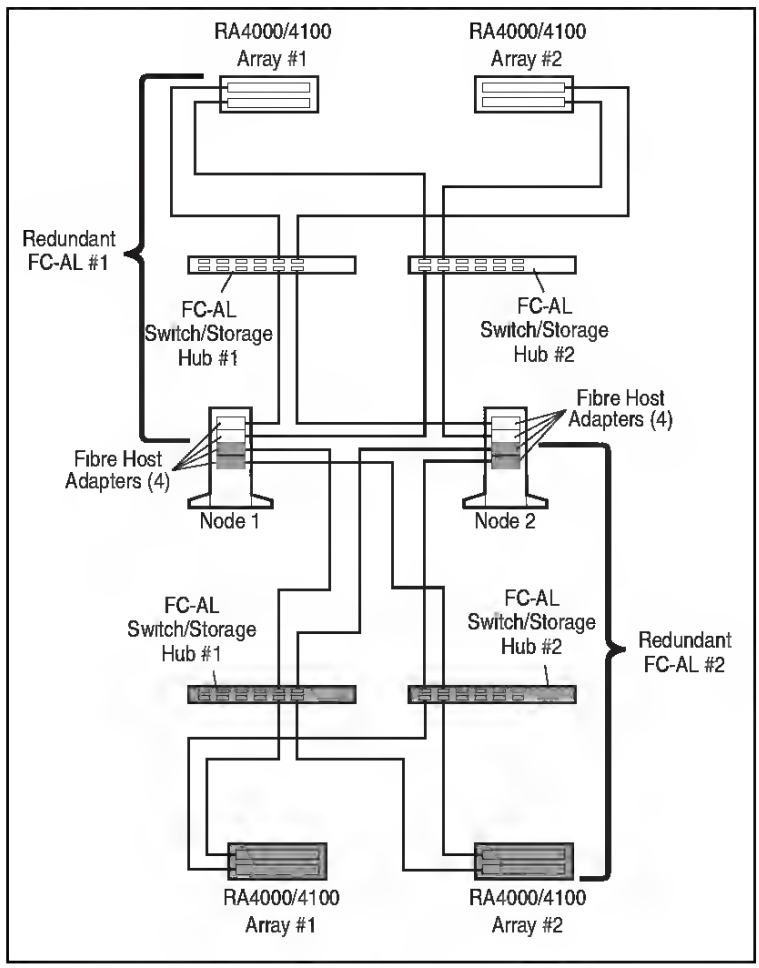

Figure 2-16. Two-node PDC/O2000 with two redundant Fibre Channel Arbitrated Loops

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Maximum Distances Between Nodes and Shared Storage Components in a Redundant FC-AL

By using standard short-wave Fibre Channel cables with Gigabit Interface Converter-Shortwave (GBIC-SW) modules, the following maximum distances apply:

- Each RA4000/RA4100 Array can be placed up to 500 meters from the Storage Hubs or FC-AL Switches to which it is cabled.
- Each Storage Hub or FC-AL Switch can be placed up to 500 meters from the Fibre Host Adapters to which it is cabled.

Figure 2-17 illustrates these maximum cable distances for a redundant FC-AL.

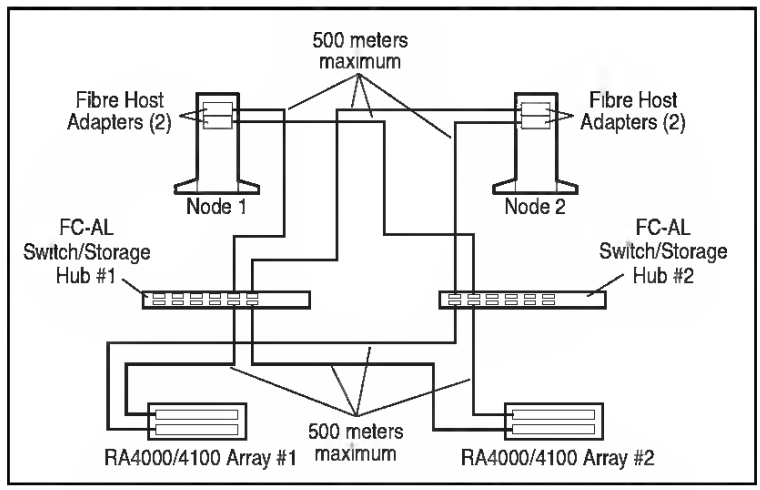

Figure 2-17. Maximum distances between PDC/O2000 cluster nodes and shared storage subsystem components in a redundant FC-AL

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I/O Data Paths in a Redundant FC-AL

A distinct I/O path connection exists between each Fibre Host Adapter in a cluster node and every array controller port in each RA4000/RA4100 Array in the redundant FC-AL.

Fibre Host Adapter-to-Storage Hub/Switch Paths

Figure 2-18 highlights the I/O data paths that run between the Fibre Host Adapters and the Storage Hubs or FC-AL Switches in a redundant FC-AL.

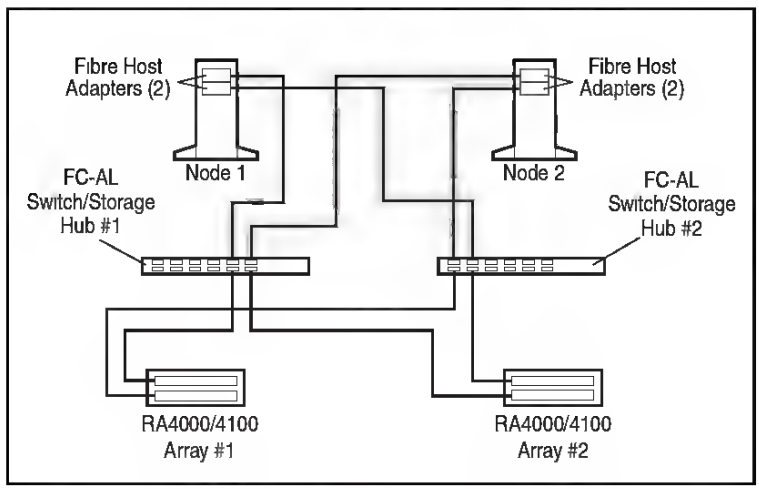

Figure 2-18. Fibre Host Adapter-to-FC-AL Switch/Storage Hub data paths

Secure Path monitors the status of the components along each active path. If Secure Path detects the failure of a Fibre Host Adapter, Fibre Channel cable, Storage Hub, or FC-AL Switch along an active path, it automatically transfers all I/O activity on that path to the components on the defined backup path.

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Storage Hub/Switch-to-Array Controller Paths

Figure 2-19 highlights the I/O data paths that run between the Storage Hubs or FC-AL Switches and the two single-port RA4000 Array Controllers in each RA4000/RA4100 Array.

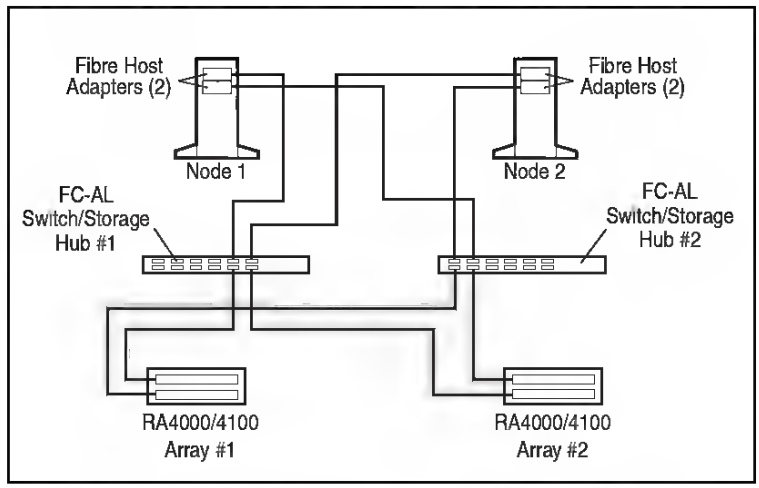

Figure 2-19. FC-AL Switch/Storage Hub-to-RA4000/RA4100 Array data paths

If any component along an active path fails, Secure Path detects the failure and automatically transfers all I/O activity to the components on the defined backup path.

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I/O Path Configuration Guidelines for Redundant Fibre Channel Arbitrated Loops

You can use either of two I/O path configurations for every redundant FC-AL in your PDC/O2000 cluster:

- Active/standby configuration
- Active/active configuration

In every redundant FC-AL, at least two Fibre Host Adapters must be installed in each node (one Fibre Host Adapter for each Storage Hub or FC-AL Switch in that redundant FC-AL).

In the active/standby configuration, only one of the two Fibre Host Adapters in each node is active at any one time; the other Fibre Host Adapter is in the standby state. The active Fibre Host Adapter is connected to the first Storage Hub or FC-AL Switch, which is connected to the active array controller in each RA4000/RA4100 Array. The standby Fibre Host Adapter is connected to the second Storage Hub or FC-AL Switch, which is connected to the standby array controller in each RA4000/RA4100 Array. The standby Fibre Host Adapter remains in the standby state unless a failover from the active I/O path occurs. In the active/standby configuration, the failure of any component along an active I/O path (Fibre Host Adapter, Storage Hub or FC-AL Switch, active array controller, or Fibre Channel cable) causes Secure Path to implement a complete failover to the components on the standby I/O path.

In the active/active configuration, both Fibre Host Adapters in each node are simultaneously active. Both are active because each Fibre Host Adapter is connected to a Storage Hub or FC-AL Switch that, in turn, is connected to an active array controller in each RA4000/RA4100 Array. Because each Fibre Host Adapter and Storage Hub or FC-AL Switch must connect to at least one active array controller, at least two RA4000/RA4100 Arrays must be present in an active/active configuration.

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See "Active/Standby Configuration Examples for Redundant FC-ALs" in this chapter for a detailed description of active/standby configuration examples for a redundant FC-AL with from one to five RA4000/RA4100 Arrays. See "Active/Active Configuration Examples for Redundant FC-ALs" for a detailed description of active/active configuration examples when two to five RA4000/RA4100 Arrays are present.

Table 2-6 identifies the features of the active/standby and active/active configurations for redundant FC-ALs.

Table 2-6
Features of Active/Standby and Active/Active Configurations for Redundant Fibre Channel Arbitrated Loops

I/O Path Configuration	Advantage	Disadvantage
Active/standby with one RA4000/RA4100 Array	Active/standby is the only I/O path configuration you can use in a redundant FC-AL that contains just one RA4000/RA4100 Array.	
Active/standby with two or more RA4000/RA4100 Arrays	Provides true cabling symmetry between the Storage Hubs or FC-AL Switches and array controllers. A Storage Hub or FC-AL Switch connects to the same array controller slot (top or bottom) in every RA4000/RA4100 Array.	Load balancing between the two Storage Hubs or FC-AL Switches is less than ideal because the connection to the active array controller in every RA4000/RA4100 Array is routed through the same Storage Hub or FC-AL Switch. The second Storage Hub or FC-AL Switch provides no active I/O pathway unless an active array controller or its cable connection to the first Storage Hub or FC-AL Switch fails.

continued

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Table 2-6
Features of Active/Standby and Active/Active Configurations for Redundant Fibre Channel Arbitrated Loops *continued*

I/O Path Configuration	Advantage	Disadvantage
Active/active with two or more RA4000/RA4100 Arrays	Provides a small but measurable improvement in I/O performance over the active/standby configuration because both Fibre Host Adapters in each node and both Storage Hubs or FC-AL Switches are simultaneously active. This improvement can be meaningful for customers with large cluster databases or high I/O transaction requirements. Provides better load balancing between the two Storage Hubs than the active/standby configuration. Both Storage Hubs or FC-AL Switches are connected to the same or equivalent numbers of both active and standby array controllers in the RA4000/RA4100 Arrays.	Does not provide true cabling symmetry between Storage Hubs or FC-AL Switches and array controllers if you consistently configure the top or rightmost array controller as the active controller. Each Storage Hub or FC-AL Switch is cabled to top (active) array controllers in some RA4000/RA4100 Arrays and bottom (standby) controllers in others. You can achieve cabling symmetry if you configure the bottom array controller in some RA4000/RA4100 Arrays as active. However, this requires using Secure Path to configure the lower array controller as active if it is in standby mode.

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I/O Path Configuration Rules for Redundant FC-ALs

The following rules must be observed in I/O path configurations for PDC/O2000 clusters with redundant FC-ALs:

- Each redundant FC-AL must use either an active/standby or active/active configuration. The active/standby or active/active configuration is confined to that redundant FC-AL.
- For each redundant FC-AL, at least two Fibre Host Adapters are installed in each cluster node (one for each Storage Hub or FC-AL Switch).
- For each redundant FC-AL, at least two Storage Hubs or FC-AL Switches (Storage Hub/FC-AL Switch #1 and Storage Hub/FC-AL Switch #2) are installed between the nodes and the RA4000/RA4100 Arrays.
- A minimum of one RA4000/RA4100 Array is required for the active/standby configuration.
- A minimum of two RA4000/RA4100 Arrays is required for the active/active configuration.
- Each RA4000/RA4100 Array must contain two array controllers to provide redundant paths.
- Only one of the two array controllers in an RA4000/RA4100 Array can be active at a given time. The other array controller is the standby controller.
- I/O path hardware components must be connected using Fibre Channel cables and GBIC-SW modules.

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Active/Standby Configuration Examples for Redundant FC-ALs

This section describes examples of active/standby configurations when one, two, three, four, and five RA4000/RA4100 Arrays are present in one redundant FC-AL of a four-node PDC/O2000. These examples represent one method for configuring active/standby configurations. They are presented here to provide a relatively simple and consistent method for building active/standby configurations.

IMPORTANT: Figures 2-20 through 2-24 show active/standby configurations for a four-node cluster. Active/standby configurations for clusters with two, three, five, or more nodes are not described here. However, the illustrated active/standby configuration examples provided should supply sufficient information for building an active/standby configuration in any PDC/O2000 cluster.

The active/standby configuration examples shown in Figures 2-20 through 2-24 follow these configuration guidelines:

- For every Fibre Host Adapter pair, the top or leftmost Fibre Host Adapter in each node is connected to the odd-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #1). This is the active Fibre Host Adapter in the pair.
- For every Fibre Host Adapter pair, the bottom or rightmost Fibre Host Adapter in each node is connected to the even-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #2). This is the standby Fibre Host Adapter in the pair.
- In each RA4000/RA4100 Array, the top (rack model) or right rear (tower model) array controller is always the active controller.

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- In each RA4000/RA4100 Array, the bottom (rack model) or left rear (tower model) array controller is always the standby controller.
- The odd-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #1) is connected to the active array controller in each RA4000/RA4100 Array.
- The even-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #2) is connected to the standby array controller in each RA4000/RA4100 Array.

NOTE: The following active/standby configurations are examples only. You are not required to follow these configurations.

For more information about installing active/standby configurations, refer to the following sections in Chapter 5, "Installation and Configuration":

- "Cabling the Fibre Host Adapters to the Storage Hubs or Switches"
- "Cabling the Storage Hubs or Switches to the RA4000 Array Controllers"

In Figures 2-20 through 2-24, active I/O path components have been shaded to distinguish them from standby (inactive) components. Black Fibre Channel cables identify connections between active components; gray cables identify connections between standby components.

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Active/Standby Configuration with One RA4000/4100 Array

Figure 2-20 shows an active/standby I/O path configuration for a redundant FC-AL in a four-node cluster with one RA4000/RA4100 Array.

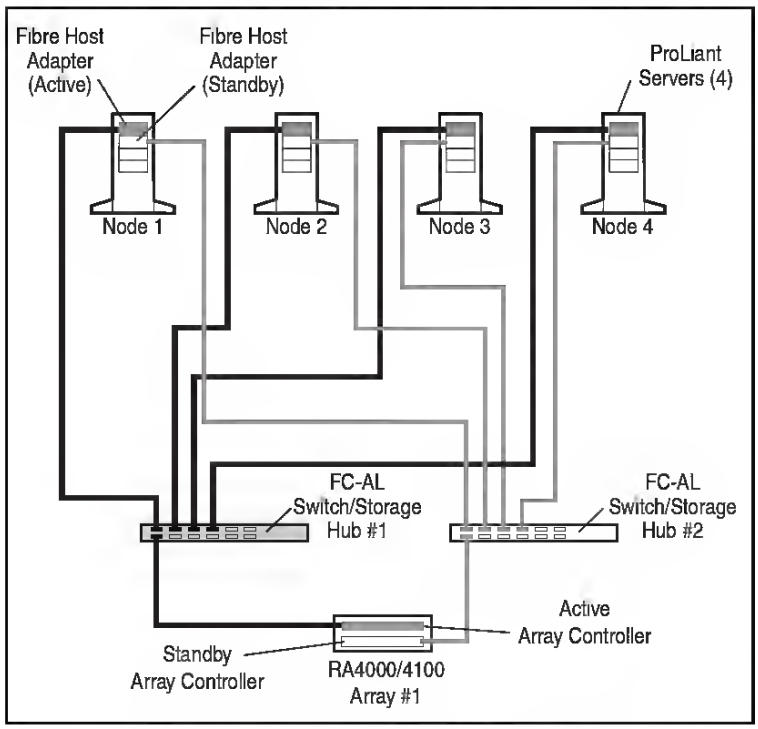

Figure 2-20. Active/standby configuration with one RA4000/RA4100 Array

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Active/Standby Configuration with Two RA4000/4100 Arrays

Figure 2-21 shows an active/standby I/O path configuration for a redundant FC-AL in a four-node cluster with two RA4000/RA4100 Arrays.

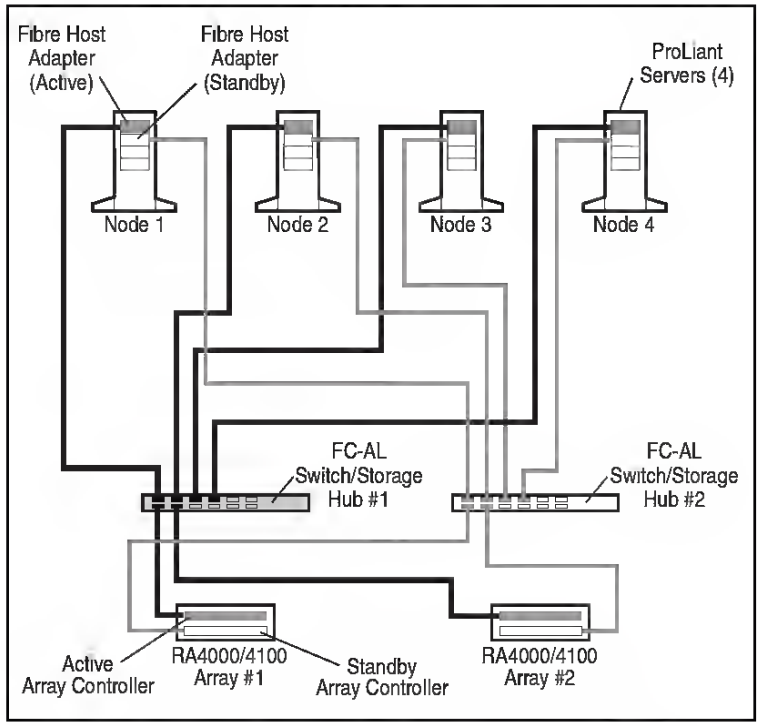

Figure 2-21. Active/standby configuration with two RA4000/RA4100 Arrays

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Active/Standby Configuration with Three RA4000/RA4100 Arrays

Figure 2-22 shows an active/standby I/O path configuration for a redundant FC-AL in a four-node cluster with three RA4000/RA4100 Arrays.

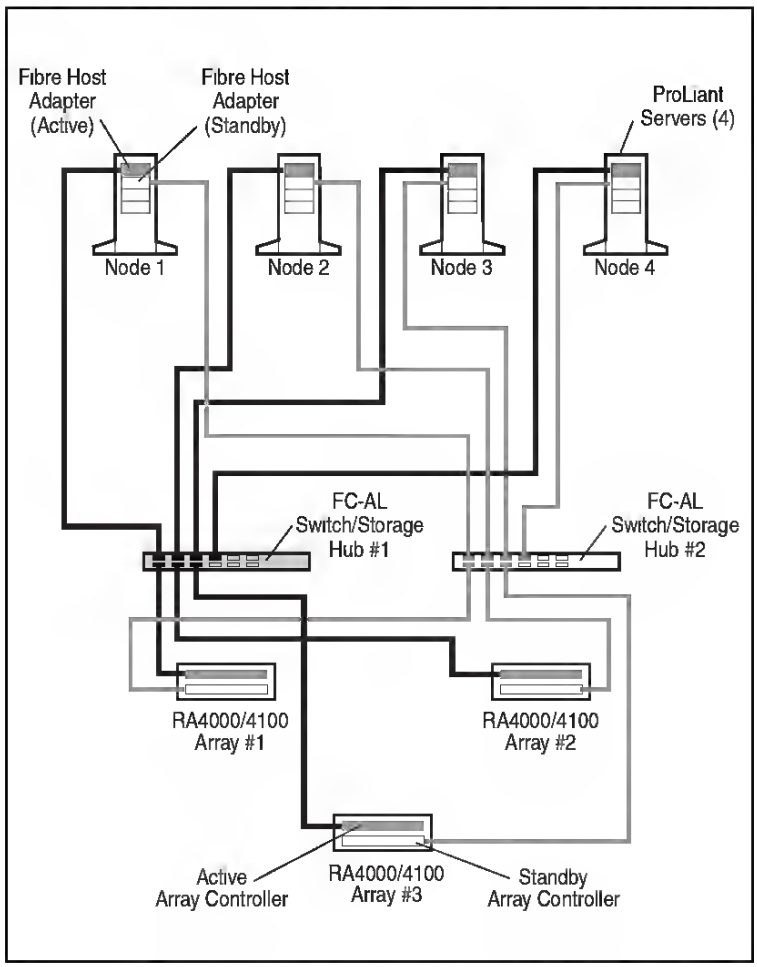

Figure 2-22. Active/standby configuration with three RA4000/RA4100 Arrays

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Active/Standby Configuration with Four RA4000/RA4100 Arrays

Figure 2-23 shows an active/standby I/O path configuration for a redundant FC-AL in a four-node cluster with four RA4000/RA4100 Arrays.

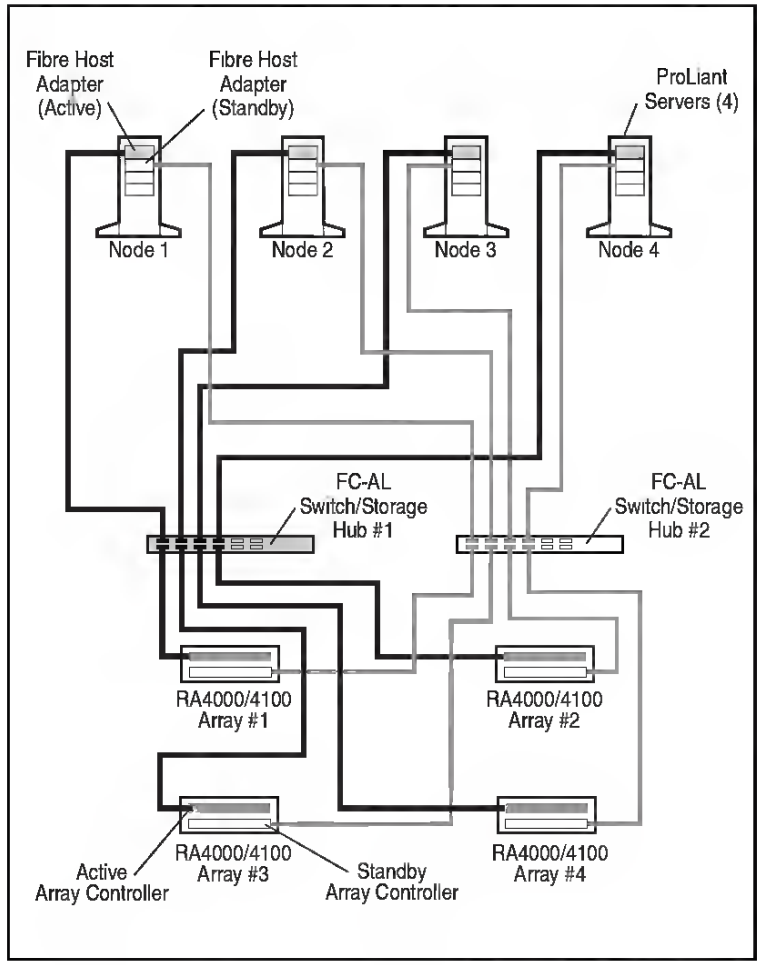

Figure 2-23. Active/standby configuration with four RA4000/RA4100 Arrays

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Active/Standby Configuration with Five RA4000/RA4100 Arrays

Figure 2-24 shows an active/standby I/O path configuration for a redundant FC-AL in a four-node cluster with five RA4000/RA4100 Arrays.

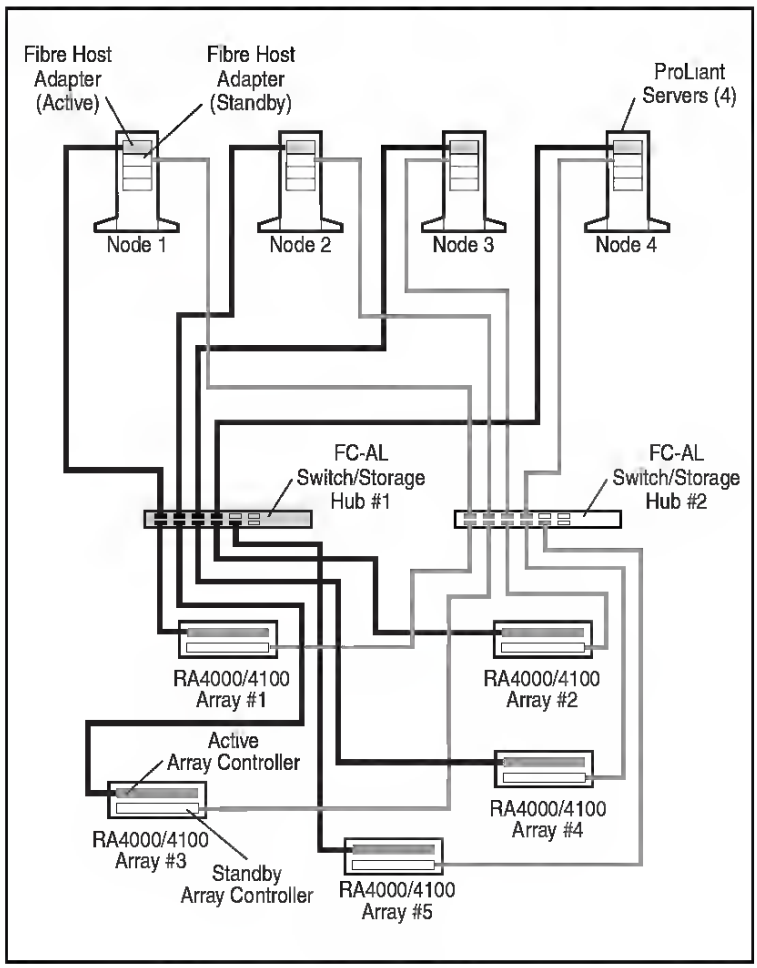

Figure 2-24. Active/standby configuration with five RA4000/RA4100 Arrays

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Active/Active Configuration Examples for Redundant FC-ALs

This section describes examples of active/active configurations when two, three, four, and five RA4000/RA4100 Arrays are present in one redundant FC-AL of a four-node PDC/O2000 cluster. These examples represent one method for configuring active/active configurations. They are presented here to provide a relatively simple and consistent method for building active/active configurations.

IMPORTANT: Figures 2-25 through 2-28 show active/active configurations for a four-node cluster. Active/active configurations for clusters with two, three, five, or more nodes are not described here. However, the illustrated active/active configuration examples provided should supply sufficient information for building an active/standby configuration in any PDC/O2000 cluster.

The active/active configuration examples shown in Figures 2-25 through 2-28 follow these configuration guidelines:

- For every Fibre Host Adapter pair, the top or leftmost Fibre Host Adapter in each node is connected to the odd-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #1). This is an active Fibre Host Adapter.
- For every Fibre Host Adapter pair, the bottom or rightmost Fibre Host Adapter in each node is connected to the even-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #2). This is also an active Fibre Host Adapter.
- In each RA4000/RA4100 Array, the top (rack model) or right rear (tower model) array controller is always the active controller.
- In each RA4000/RA4100 Array, the bottom (rack model) or left rear (tower model) array controller is always the standby controller.
- The odd-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #1) is connected to the active array controller in each odd-numbered RA4000/RA4100 Array (1, 3, and 5).
- The odd-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #2) is connected to the standby array controller in each even-numbered RA4000/RA4100 Array (2 and 4).

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- The even-numbered Storage Hub or FC-AL Switch (Storage Hub/FC-AL Switch #2) is connected to the active array controller in each even-numbered RA4000/RA4100 Array (2 and 4).
- The even-numbered Storage Hub or FC-AL Switch is connected to the standby array controller in each odd-numbered RA4000/RA4100 Array (1, 3, and 5).

NOTE: The following active/active configurations are examples only. You are not required to follow these configurations.

For more information about installing active/active configurations, refer to these sections in Chapter 5, "Installation and Configuration":

- Cabling the Fibre Host Adapters to the Storage Hubs or Switches
- Cabling the Storage Hubs or Switches to the RA4000 Array Controllers

In Figures 2-25 through 2-28, active I/O path components have been shaded to distinguish them from standby (inactive) components. Black Fibre Channel cables identify connections between active components; gray cables identify connections between standby components.

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Active/Active Configuration with Two RA4000/RA4100 Arrays

Figure 2-25 shows an active/active I/O path configuration for a redundant FC-AL in a four-node cluster with two RA4000/RA4100 Arrays.

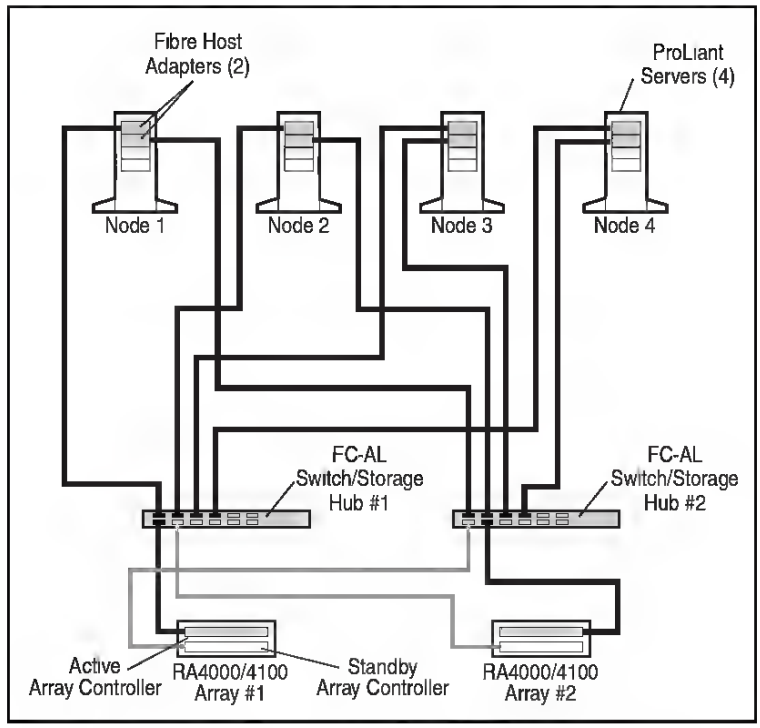

Figure 2-25. Active/active configuration with two RA4000/RA4100 Arrays

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Active/Active Configuration with Three RA4000/RA4100 Arrays

Figure 2-26 shows an active/active I/O path configuration for a redundant FC-AL in a four-node cluster with three RA4000/RA4100 Arrays.

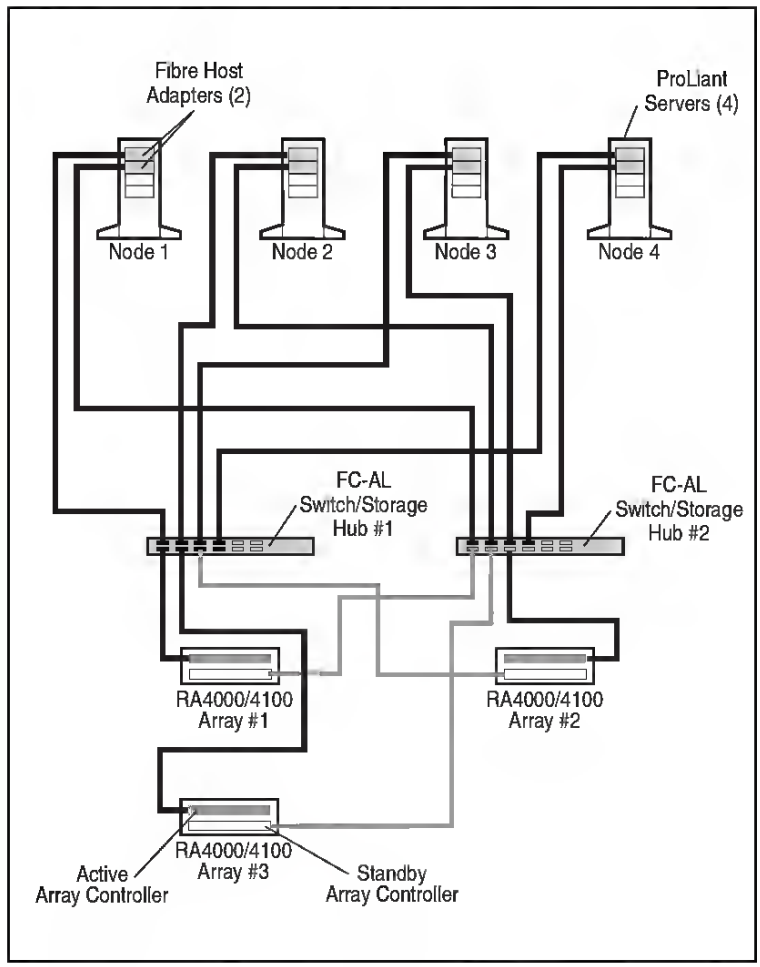

Figure 2-26. Active/active configuration with three RA4000/RA4100 Arrays

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Active/Active Configuration with Four RA4000/RA4100 Arrays

Figure 2-27 shows an active/active I/O path configuration for a redundant FC-AL in a four-node cluster with four RA4000/RA4100 Arrays.

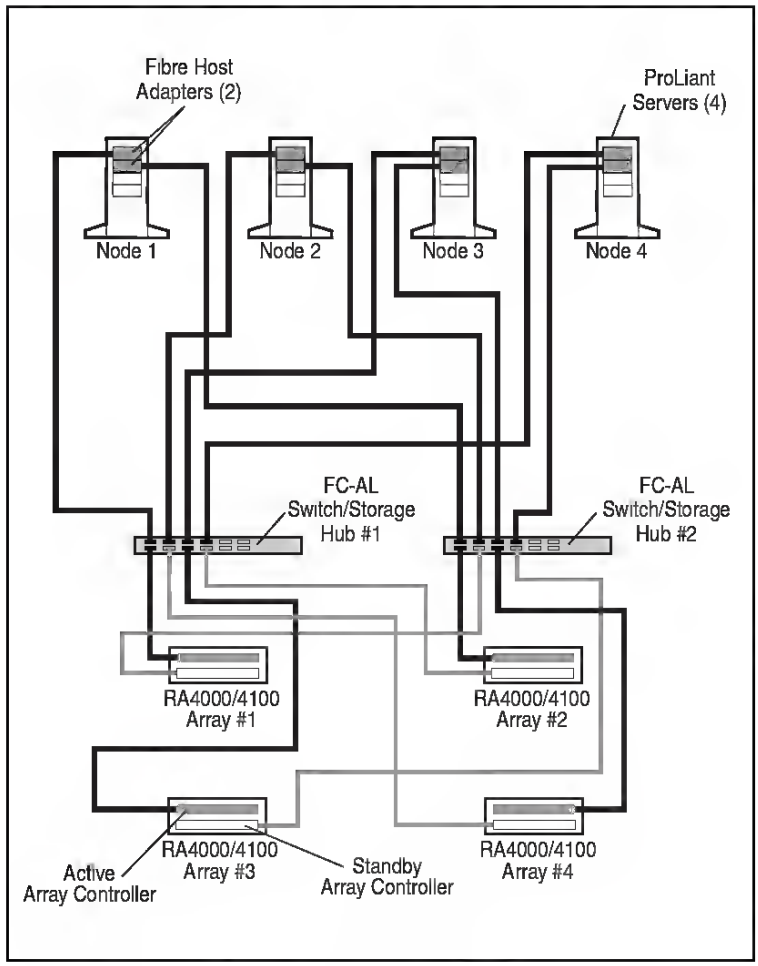

Figure 2-27. Active/active configuration with four RA4000/RA4100 Arrays

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Active/Active Configuration with Five RA4000/RA4100 Arrays

Figure 2-28 shows an active/active I/O path configuration for a redundant FC-AL in a four-node cluster with five RA4000/RA4100 Arrays.

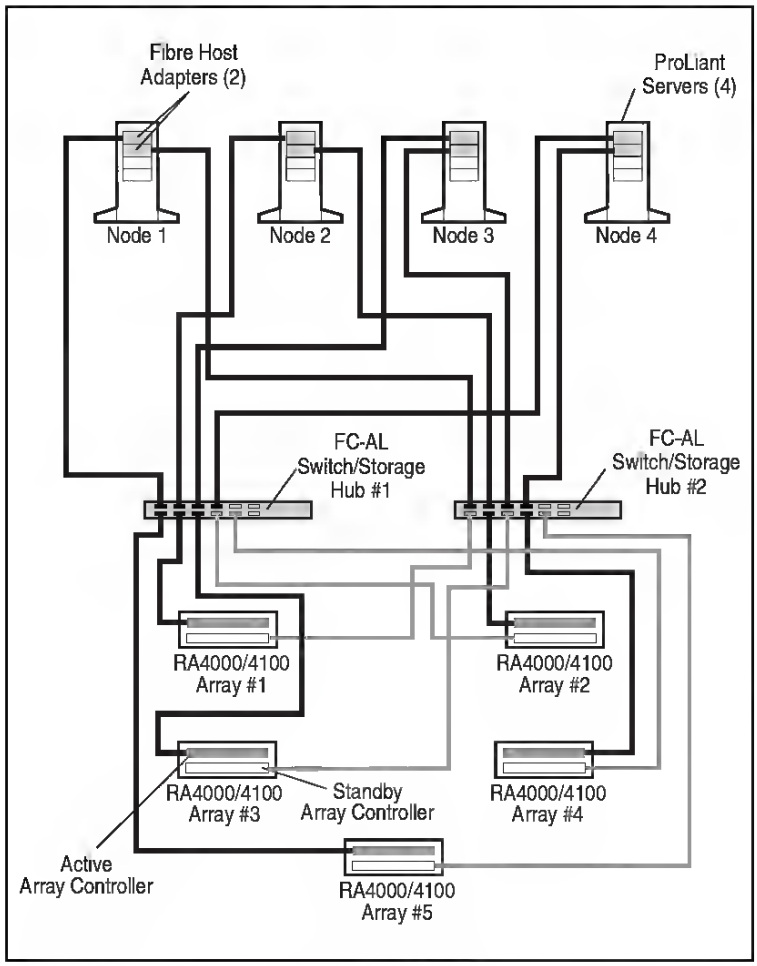

Figure 2-28. Active/active configuration with five RA4000/RA4100 Arrays

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Summary of I/O Path Failure and Failover Scenarios for Redundant FC-ALs

Table 2-7 identifies possible I/O path failure events in redundant FC-ALs for active/standby configurations with one RA4000/RA4100 Array and the failover response, if any, implemented by Secure Path for each failure.

Table 2-7
I/O Path Failure and Failover Scenarios in Redundant FC-ALs for Active/Standby Configurations With One RA4000/RA4100 Array

Description of Failure	Failover Response
The active array controller in the RA4000/RA4100 Array fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
The standby array controller in the RA4000/RA4100 Array fails.	None
The Fibre Channel cable connection between the active array controller and its Storage Hub or FC-AL Switch is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
The Fibre Channel cable connection between the standby array controller and its Storage Hub or FC-AL Switch is broken.	None
The Storage Hub or FC-AL Switch connected to the active array controller fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
The Storage Hub or FC-AL Switch connected to the standby array controller fails.	None
The Fibre Channel cable connection between a Fibre Host Adapter and the Storage Hub or FC-AL Switch connected to the active array controller is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.

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Table 2-7
I/O Path Failure and Failover Scenarios in Redundant FC-ALs for Active/Standby Configurations With One RA4000/RA4100 Array *continued*

Description of Failure	Failover Response
The Fibre Channel cable connection between a Fibre Host Adapter and the Storage Hub or FC-AL Switch connected to the standby array controller is broken.	None
A Fibre Host Adapter connected to the Storage Hub or FC-AL Switch that connects to the active array controller fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in the RA4000/RA4100 Array, and Fibre Channel cables.
A Fibre Host Adapter connected to the Storage Hub or FC-AL Switch that connects to the standby array controller fails.	None

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Table 2-8 identifies possible I/O path failure events for active/standby configurations with two or more RA4000/RA4100 Arrays and the failover response, if any, implemented by Secure Path for each failure.

Table 2-8
I/O Path Failure and Failover Scenarios in Redundant FC-ALs for Active/Standby Configurations With Two or More RA4000/RA4100 Arrays

Description of Failure	Failover Response
The active array controller in one RA4000/RA4100 Array fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.
The standby array controller in one RA4000/RA4100 Array fails.	None
The Fibre Channel cable connection between the active array controller in one RA4000/RA4100 Array and its Storage Hub or FC-AL Switch is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.
The Fibre Channel cable connection between the standby array controller in one RA4000/RA4100 Array and its Storage Hub or FC-AL Switch is broken.	None
The Storage Hub or FC-AL Switch that is connected to the active array controller in each RA4000/RA4100 Array fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.
The Storage Hub or FC-AL Switch that is connected to the standby array controller in each RA4000/RA4100 Array fails.	None

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Table 2-8
I/O Path Failure and Failover Scenarios in Redundant FC-ALs for Active/Standby Configurations With Two or More RA4000/RA4100 Arrays *continued*

Description of Failure	Failover Response
The Fibre Channel cable connection between the Storage Hub or FC-AL Switch that is connected to the active array controllers and a Fibre Host Adapter is broken.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in the each RA4000/RA4100 Array, and Fibre Channel cables.
The Fibre Channel cable connection between the Storage Hub or FC-AL Switch that is connected to the standby array controllers and a Fibre Host Adapter is broken.	None
A Fibre Host Adapter connected to the Storage Hub or FC-AL Switch that is connected to the active array controllers fails.	Secure Path forces a complete failover to the standby I/O path components, including the standby Fibre Host Adapter in each node, the other Storage Hub or FC-AL Switch, the standby array controller in each RA4000/RA4100 Array, and Fibre Channel cables.
A Fibre Host Adapter connected to the Storage Hub or FC-AL Switch that is connected to the standby array controllers fails.	None

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Table 2-9 identifies possible I/O path failure events in redundant FC-ALs for active/active configurations with two or more RA4000/RA4100 Arrays and the failover response, if any, implemented by Secure Path for each failure.

Table 2-9
I/O Path Failure and Failover Scenarios in Redundant FC-ALs for Active/Active Configurations With Two or More RA4000/RA4100 Arrays

Description of Failure	Failover Response
The active array controller in one RA4000/RA4100 Array fails.	Secure Path makes the standby array controller in the RA4000/RA4100 Array active and reroutes I/O activity to that array controller. The Storage Hub or FC-AL Switch that is connected to the new active array controller becomes the active I/O path to this RA4000/RA4100 Array. In each node, I/O activity between the Fibre Host Adapter that is connected to the failed array controller is rerouted to the second Fibre Host Adapter in the pair, but only along the I/O path to the affected RA4000/RA4100 Array. The first Fibre Host Adapter in each node continues to be the active I/O path for active array controllers in other RA4000/RA4100 Arrays to which it is connected.
The standby array controller in one RA4000/RA4100 Array fails.	None
The Fibre Channel cable connection between the active array controller in one RA4000/RA4100 Array and its Storage Hub or FC-AL Switch is broken.	Secure Path makes the active array controller to which the failed cable is connected inactive. The standby array controller in the RA4000/RA4100 Array becomes active. I/O activity is routed through the Fibre Channel cable installed to the new active array controller and the other Storage Hub or FC-AL Switch. In each node, I/O activity between the Fibre Host Adapter that is connected to the failed array controller is rerouted to the second Fibre Host Adapter in the pair, but only along the I/O path to the affected RA4000/RA4100 Array. The first Fibre Host Adapter in each node continues to be the active I/O path for active array controllers in other RA4000/RA4100 Arrays to which it is connected.
The Fibre Channel cable connection between the standby array controller in one RA4000/RA4100 Array and its Storage Hub or FC-AL Switch is broken.	None

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Table 2-9
I/O Path Failure and Failover Scenarios in Redundant FC-ALs for Active/Active Configurations With Two or More RA4000/RA4100 Arrays *continued*

Description of Failure	Failover Response
A Storage Hub or FC-AL Switch fails.	Secure Path makes each active array controller to which the failed Storage Hub or FC-AL Switch is connected inactive. The standby array controller in each affected RA4000/RA4100 Array becomes the active array controller. The Storage Hub or FC-AL Switch that is connected to the new active array controllers becomes the active I/O path for these RA4000/RA4100 Arrays. In each node, the Fibre Host Adapter that is connected to the failed Storage Hub or FC-AL Switch becomes inactive, and all I/O activity is rerouted through the other Fibre Host Adapter in the pair and the remaining active Storage Hub or FC-AL Switch.
The Fibre Channel cable connection between a Storage Hub or FC-AL Switch and a Fibre Host Adapter in one node is broken.	Secure Path makes all I/O path connections between the affected Fibre Host Adapter and active array controllers inactive. The standby array controller in every affected RA4000/RA4100 Array becomes the active array controller. The Storage Hub or FC-AL Switch connected to the newly active array controllers becomes the active I/O path for the entire FC-AL. The Storage Hub or FC-AL Switch connected to the failed Fibre Channel cable becomes inactive. The second Fibre Host Adapter in each node, which is connected to the only active Storage Hub or FC-AL Switch, becomes the only active Fibre Host Adapter in the node's pair.
A Fibre Host Adapter in a node fails.	Secure Path makes all I/O path connections between the affected Fibre Host Adapter and active array controllers inactive. The standby array controller in every affected RA4000/RA4100 Array becomes the active array controller. The Storage Hub or FC-AL Switch connected to the newly active array controllers becomes the active I/O path for the entire FC-AL. The Storage Hub or FC-AL Switch connected to the failed Fibre Host Adapter becomes inactive. The second Fibre Host Adapter in each node, which is connected to the only active Storage Hub or FC-AL Switch, becomes the only active Fibre Host Adapter in the node's pair.

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Cluster Interconnect Options

The cluster interconnect is the data path over which all of the nodes in a cluster communicate. The nodes use the cluster interconnect data path to:

- Communicate individual resource and overall cluster status.
- Send and receive heartbeat signals.
- Coordinate database locks through the Oracle Integrated Distributed Lock Manager.

NOTE: Several terms for *cluster interconnect* are used throughout the industry. Others are: private LAN, private interconnect, system area network (SAN), and private network. Throughout this guide, the term *cluster interconnect* is used.

A PDC/O2000 cluster running Oracle8*i* Parallel Server uses an Ethernet cluster interconnect. An Ethernet cluster interconnects can be redundant or non-redundant. A redundant cluster interconnect is recommended because it uses redundant hardware to provide fault tolerance along the entire cluster interconnect path.

Ethernet Cluster Interconnect

IMPORTANT: The cluster management software for the Ethernet cluster interconnect requires the use of TCP/IP. When configuring the Ethernet cluster interconnect, be sure to enable TCP/IP.

NOTE: Refer to the technical white paper *Supported Ethernet Interconnects for Compaq Parallel Database Clusters Using Oracle Parallel Server* (ECG062/0299) for detailed information about configuring redundant and non-redundant Ethernet cluster interconnects. This document is available at

www.compaq.com/support/techpubs/whitepapers

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Non-Redundant Ethernet Cluster Interconnect Components

The following components are used in a non-redundant Ethernet cluster interconnect:

- One Ethernet adapter in each cluster node
- Ethernet cables and a switch or hub
  - For two-node PDC/O2000 clusters, you can either use one Ethernet crossover cable or one 100-Mbit/second Ethernet switch or hub and standard Ethernet cables to connect the two servers.
  - For PDC/O2000 clusters with three or more nodes, you use one 100-Mbit/second Ethernet switch and standard Ethernet cables to connect the servers.

Redundant Ethernet Cluster Interconnect Components

The following components are used in a redundant Ethernet cluster interconnect:

- Two Ethernet adapters in each cluster node
- Ethernet cables and switches or hubs
  - For two-node PDC/O2000 clusters, you can use two 100-Mbit/second Ethernet switches or hubs with cables to connect the servers.
  - For PDC/O2000 clusters with three or more nodes, you use two 100-Mbit/second Ethernet switches connected by Ethernet cables to a separate Ethernet adapter in each server.

NOTE: In a redundant Ethernet cluster configuration, one Ethernet crossover cable must be installed between the two Ethernet switches or hubs that are dedicated to the cluster interconnect.

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Ethernet Cluster Interconnect Adapters

To implement the Ethernet cluster interconnect, each cluster node must be equipped with Ethernet adapters capable of 100-Mbit/second transfer rates. Some adapters may be capable of operating at both 10-Mbit/second and 100-Mbit/second; however, Ethernet adapters used for the cluster interconnect must run at 100-Mbit/second.

The Ethernet adapters must have passed Windows 2000 Advanced HCT certification.

NOTE: If you are using dual-port Ethernet adapters in a non-redundant Ethernet cluster interconnect, you can use one port for the Ethernet cluster interconnect and the second port for the client LAN. Refer to the technical white paper *Supported Ethernet Interconnects for Compaq Parallel Database Clusters Using Oracle Parallel Server* for detailed information about configuring redundant Ethernet cluster interconnects. This document is available at

www.compaq.com/support/techpubs/whitepapers

For detailed information about installing an Ethernet cluster interconnect, see Chapter 5, "Installation and Configuration."

Ethernet Switch

IMPORTANT: The Ethernet switch or switches used with the Ethernet cluster interconnect must be dedicated to the cluster interconnect. They cannot be connected to the client network (LAN) or to servers that are not part of the PDC/O2000 cluster.

When an Ethernet cluster interconnect is used in a cluster with three or more nodes, a 100-Mbit/second Ethernet switch is required for the cluster interconnect path. The 100-Mbit/second Ethernet switch handles the higher network loads essential to the uninterrupted operation of the cluster. An Ethernet hub cannot be used.

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Ethernet Cluster Interconnect Diagrams

Figure 2-29 shows the non-redundant Ethernet cluster interconnect components used in a two-node PDC/O2000 cluster. These components include a dual-port Ethernet adapter in each node. The top port on each adapter connects by Ethernet crossover cable to the top port on the adapter in the other node. The bottom port on each adapter connects by Ethernet cable to the client LAN switch or hub.

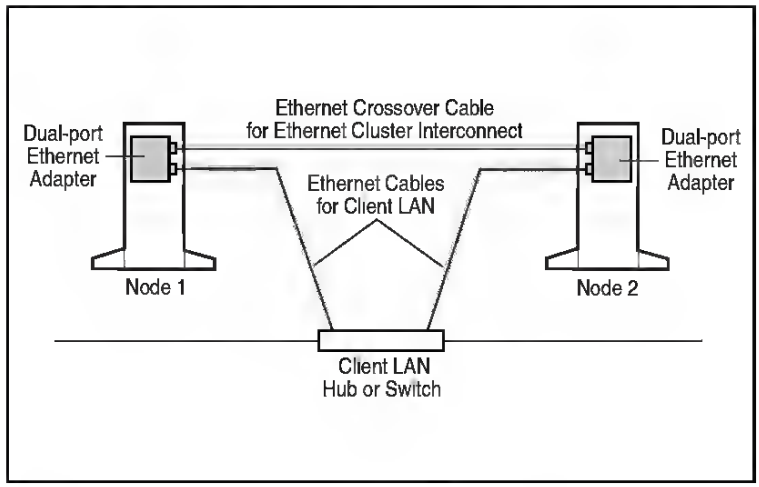

Figure 2-29. Non-redundant Ethernet cluster interconnect using a crossover cable

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Figure 2-30 shows another option for a non-redundant Ethernet cluster interconnect in a two-node PDC/O2000 cluster. These include an Ethernet adapter in each node connected by Ethernet cables to an Ethernet switch or hub.

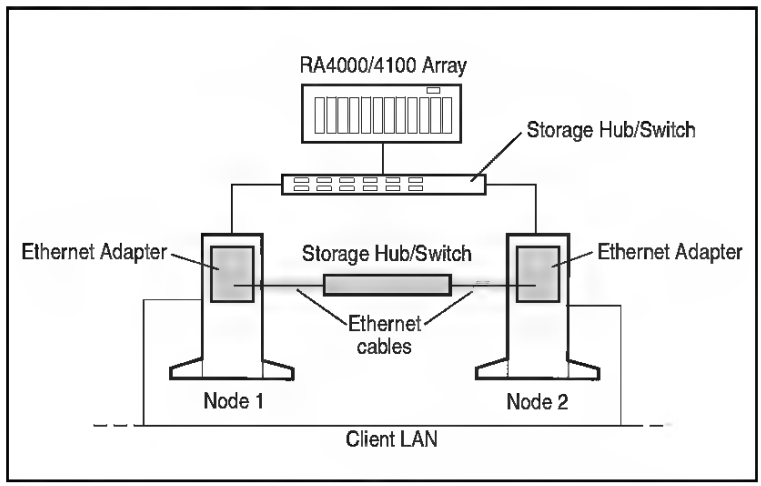

Figure 2-30. Non-redundant Ethernet cluster using an Ethernet switch or hub

Because Ethernet switches are required in PDC/O2000 clusters with three or more nodes, using an Ethernet switch instead of a crossover cable makes it easier to upgrade the cluster interconnect if more servers are added to the cluster.

IMPORTANT: Crossover cables and Ethernet hubs cannot be used in PDC/O2000 clusters with a redundant Ethernet cluster interconnect or in PDC/O2000 clusters with three or more nodes.

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Figure 2-31 shows the redundant Ethernet cluster interconnect components used in a two-node PDC/O2000 cluster.

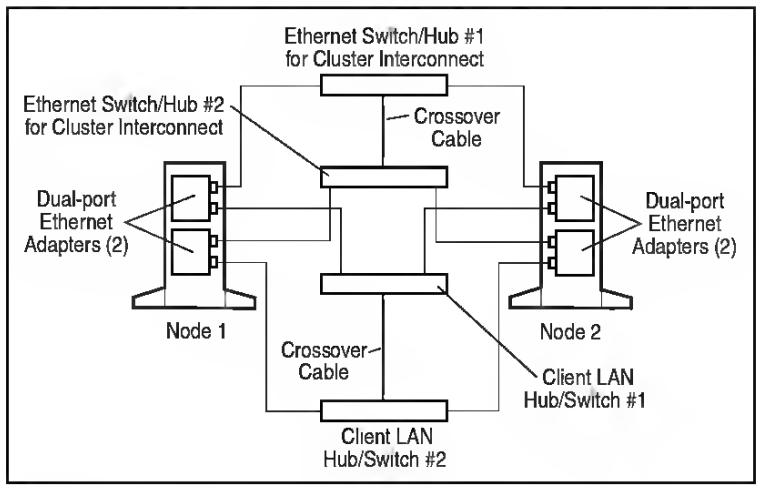

Figure 2-31. Redundant Ethernet cluster interconnect for a two-node PDC/O2000 cluster

These components include two dual-port Ethernet adapters in each cluster node. The top port on each adapter connects by Ethernet cable to one of two Ethernet switches or hubs provided for the cluster interconnect. The bottom port on each adapter connects by Ethernet cable to the client LAN for the cluster. A crossover cable is installed between the two Ethernet switches or hubs used in the Ethernet cluster interconnect.

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Local Area Network

NOTE: For the PDC/O2000, the client LAN and the cluster interconnect must be treated as separate networks. Do not use either network to handle the other network's traffic.

Every client/server application requires a local area network, or LAN, over which client machines and servers communicate. In the case of a cluster, the hardware components of the client LAN are no different than in a standalone server configuration.

The software components used by network clients should have the ability to detect node failures and automatically reconnect the client to another cluster node. For example, Net8, Oracle Call Interface (OCI) and Transaction Process Monitors can be used to address this issue.

NOTE: For complete information on how to ensure client auto-reconnect in an Oracle8*i* Parallel Server environment, contact your Oracle representative.

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Chapter 3

Cluster Software Components

Overview of the Cluster Software

The Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000) combines software from several leading computer vendors. The integration of these components creates a stable cluster management environment in which the Oracle database can operate.

For the PDC/O2000, the cluster management software is a combination of Compaq operating system dependent modules (OSDs) and this Oracle software:

- Oracle8*i* Enterprise Edition with the Oracle8*i* Parallel Server Option

  NOTE: For information about currently-supported software revisions for the, refer to the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* at

  www.compaq.com/solutions/enterprise/ha-pdc.html

Microsoft Windows 2000 Advanced Server

This version of the PDC/O2000 supports only Microsoft Windows 2000 Advanced Server with Service Pack 1 or later.

NOTE: The PDC/O2000 does not work in conjunction with Microsoft Cluster Server. Do not install Microsoft Cluster Server on any of the cluster nodes.

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Compaq Software

Compaq offers an extensive set of features and optional tools to support effective configuration and management of the PDC/O2000:

- Compaq *SmartStart*™ and Support Software
- Compaq System Configuration Utility
- Compaq Array Configuration Utility
- Fibre Channel Fault Isolation Utility
- *Compaq Insight Manager*™
- Compaq Insight Manager XE
- Compaq Options *ROMPaq*™
- Compaq StorageWorks Secure Path for Windows 2000
- Compaq operating system dependent modules (OSDs)

Compaq SmartStart and Support Software

SmartStart, which is located on the SmartStart and Support Software CD, is the best way to configure Windows 2000 Advanced Server on a PDC/O2000 cluster. SmartStart uses an automated step-by-step process to configure the operating system and load the system software.

The Compaq SmartStart and Support Software CD also contains device drivers and utilities that enable you to take advantage of specific capabilities offered on Compaq products. These drivers are provided for use with Compaq hardware only.

The PDC/O2000 requires version 4.9 or later of the SmartStart and Support Software CD. For information about SmartStart, refer to the Compaq Server Setup and Management pack.

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Compaq System Configuration Utility

The SmartStart and Support Software CD also contains the Compaq System Configuration Utility. This utility is the primary means to configure hardware devices within your servers, such as I/O addresses, boot order of disk controllers, and so on.

For information about the System Configuration Utility, see the Compaq Server Setup and Management pack.

Compaq Array Configuration Utility

The Compaq Array Configuration Utility, found on the Compaq SmartStart and Support Software CD, is used to configure the hardware aspects of any disk drives attached to an array controller, including the non-shared drives in the servers and the shared drives in the Compaq StorageWorks RAID Array 4000s (RA4000 Arrays) or Compaq StorageWorks RAID Array 4100s (RA4100 Arrays).

The Array Configuration Utility also allows you to configure RAID levels and to add disk drives or RA4000/RA4100 Arrays to an existing configuration.

For information about the Array Configuration Utility, see the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.

Fibre Channel Fault Isolation Utility

The SmartStart and Support Software CD also contains the Fibre Channel Fault Isolation Utility (FFIU). The FFIU verifies the integrity of a new or existing redundant Fibre Channel Arbitrated Loop (FC-AL). This utility provides fault detection and help in locating a failing device on a redundant FC-AL.

For more information about the FFIU, see the Compaq SmartStart and Support Software CD.

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Compaq Insight Manager

Compaq Insight Manager, loaded from the Compaq Management CD, is a software utility used to collect information about the servers in the cluster. Compaq Insight Manager performs these functions:

- Monitors server fault conditions and status
- Forwards server alert fault conditions
- Remotely controls servers

The Integrated Management Log is used to collect and feed data to Compaq Insight Manager. This log is used with the Compaq Integrated Management Display (IMD), the optional Remote Insight controller, and SmartStart.

In Compaq servers, each hardware subsystem, such as non-shared disk storage, system memory, and system processor, has a robust set of management capabilities. Compaq Full Spectrum Fault Management notifies the end user of impending fault conditions.

For information about Compaq Insight Manager, refer to the documentation you received with your Compaq ProLiant server.

Compaq Insight Manager XE

Compaq Insight Manager XE is a Web-based management system. It can be used in conjunction with Compaq Insight Manager agents as well as its own Web-enabled agents. This browser-based utility provides increased flexibility and efficiency for the administrator.

Compaq Insight Manager XE is an optional CD available upon request from the Compaq System Management website at

www.compaq.com/sysmanage

Compaq Options ROMPaq

The Compaq Options ROMPaq diskettes allow a user to upgrade the ROM Firmware images for Compaq System product options, such as array controllers, disk drives, and tape drives used for non-shared storage.

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Compaq StorageWorks Secure Path for Windows 2000

Compaq StorageWorks Secure Path for Windows 2000 (Secure Path) must be installed on each server (node) in the PDC/O2000. Secure Path monitors all I/O paths to the storagesets in the shared storage subsystems. If any component along an active I/O path fails, Secure Path detects this failure and automatically reroutes I/O activity through the defined backup path. Failovers are transparent and non-disruptive to applications.

Secure Path Manager is the client application used to manage multiple path StorageWorks RAID array configurations. Secure Path Manager displays a graphical presentation of the current multiple I/O path environment and indicates the location and state of all configured storage units on each path. To facilitate load balancing, Secure Path Manager provides the capability to move storagesets from their configured paths to other paths during normal cluster operation. Secure Path Manager can be run locally at the cluster nodes or remotely at a management station.

Compaq Operating System Dependent Modules

Compaq supplies low-level services, called operating system dependent modules (OSDs), which are required by Oracle8*i* Parallel Server. The OSD layer monitors critical clustering hardware components, constantly relaying cluster state information to Oracle8*i* Parallel Server. Oracle8*i* Parallel Server monitors this information and takes pertinent action as needed.

For example, the OSD layer is responsible for monitoring the cluster interconnect of each node in the cluster. The OSD layer determines if one of the nodes is no longer responding to the cluster heartbeat. If the node still does not respond, the OSD layer determines it is unavailable. The OSD layer evicts the node from the cluster and informs Oracle8*i* Parallel Server. Oracle8*i* Parallel Server recovers the part of the database affected by that node, and reconfigures the cluster with the remaining nodes.

OSDs for Oracle8*i* Parallel Server

For a detailed description of how the OSD layer interacts with Oracle8*i* Parallel Server, refer to the *Oracle8i Parallel Server Setup and Configuration Guide.*

The OSD software is found on the Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Microsoft Windows 2000 CD. This CD is supplied in the cluster kit for the Compaq Parallel Database Cluster Model PDC/O2000 for Windows 2000.

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Oracle Software

The PDC/O2000 supports Oracle8*i* software. If you are using a release other than Oracle8*i* Release 8.1.7, confirm that the release has been certified for the PDC/O2000 on the Compaq website at

www.compaq.com/solutions/enterprise/ha-pdc.html

Oracle8*i* Server Enterprise Edition

The Oracle8*i* Server Enterprise Edition provides the following:

- Oracle8*i* Server
- Oracle8*i* Parallel Server Option
- Oracle8*i* Enterprise Manager

Oracle8*i* Server

Oracle8*i* Server is the database application software and must be installed on each node in the PDC/O2000.

Refer to the documentation provided with the Oracle8*i* Server software for additional information.

Oracle8*i* Parallel Server Option

Oracle8*i* Parallel Server Option is the key component in the Oracle8*i* clustering architecture. Oracle8*i* Parallel Server allows the database server to divide its workload among the physical cluster nodes. This is accomplished by running a distinct instance of Oracle8*i* Server on each node in the PDC/O2000.

Oracle8*i* Parallel Server manages the interaction between these instances. Through its Integrated Distributed Lock Manager, Oracle8*i* Parallel Server manages the ownership of database records that are requested by multiple instances.

At a lower level, Oracle8*i* Parallel Server monitors cluster membership. It interacts with the OSDs, exchanging information about the state of each cluster node.

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For additional information, refer to:

- *Oracle8i Parallel Server Setup and Configuration Guide*
- Other Oracle documentation for Oracle8*i* Server and Oracle8*i* Parallel Server provided with the Oracle software

Oracle8*i* Enterprise Manager

Oracle8*i* Enterprise Manager is responsible for monitoring the state of both the database entities and the cluster members. It primarily manages the software components of the cluster. Hardware components are managed with Compaq Insight Manager.

Do not install Oracle8*i* Enterprise Manager on any of the PDC/O2000 nodes. To conserve space for cluster resources (memory, processes), it must be installed on a separate server that is running Oracle8*i* and has network access to the cluster nodes. Before installing Oracle8*i* Enterprise Manager, read its documentation to ensure it is installed and configured correctly for an Oracle8*i* Parallel Server environment.

Oracle8*i* Certification

To ensure that Oracle8*i* Parallel Server is used in a compatible hardware environment, Oracle has established a certification process, which is a series of test suites designed to stress an Oracle8*i* Parallel Server implementation and verify stability and full functionality.

All hardware providers who choose to deliver platforms for use with Oracle8*i* Parallel Server must demonstrate the successful completion of the Oracle8*i* Parallel Server for Windows 2000 Certification. Neither Oracle nor Compaq will support any implementation of Oracle8*i* Parallel Server that does not strictly conform to the configurations certified with this process. For a complete list of certified Compaq servers, see the *Compaq Parallel Database Cluster Model PDC/02000 Certification Matrix for Windows 2000* at

www.compaq.com/solutions/enterprise/ha-pdc.html

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Application Failover and Reconnection Software

When a network client computer operates in a clustered environment, it must be more resilient than when operating with a stand-alone server. Because a client can access the database through any of the cluster nodes, the failure of the connection to a node does not have to prevent the client from reattaching to the cluster and continuing its work.

Oracle clustering software provides the capability to allow the automatic reconnection of a client and application failover in the event of a node failure. To implement this application and connection failover, a software interface between the Oracle software and the client must be written.

Such a software interface would be responsible for detecting when the client's cluster node is no longer available and then connecting the client to one of the remaining, operational cluster nodes.

NOTE: For complete information on how to ensure client auto-reconnect in an Oracle Parallel Server environment, contact your Oracle representative.

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Chapter 4

Cluster Planning

Before connecting any cables or powering on any hardware on your Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000), it is important that you understand how all the various cluster components fit together to meet your operational requirements. The major topics discussed in this chapter are:

- Site planning
- Capacity planning for cluster hardware
- Planning cluster configurations for redundant Fibre Channel Fabrics
- Planning cluster configurations for redundant Fibre Channel Arbitrated Loops
- RAID planning
- Planning the grouping of physical disk storage space
- Disk drive planning
- Network planning

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Site Planning

You must carefully select and prepare the site to ensure a smooth installation and a safe and efficient work environment. To select and prepare a location for your cluster, consider the following:

- The path from the receiving dock to the installation area
- Availability of appropriate equipment and qualified personnel
- Space for unpacking, installing, and servicing the computer equipment
- Sufficient floor strength for the computer equipment
- Cabling requirements, including the placement of network and Fibre Channel cables within one room (under the subfloor, on the floor, or overhead) and possibly between rooms
- Client LAN resource planning, including the number of hubs or switches and cables to connect to the cluster nodes
- Environmental conditions, including temperature, humidity, and air quality
- Power, including voltage, current, grounding, noise, outlet type, and equipment proximity

IMPORTANT: Carefully review the power requirements for your cluster components to identify special electrical supply needs in advance.

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Capacity Planning for Cluster Hardware

Capacity planning determines how much computer hardware is needed to support the applications and data on your clustered servers. Given the size of your database and the performance you expect, you must decide how many servers and shared storage arrays the cluster needs.

Compaq ProLiant Servers

The number of servers you install in a PDC/O2000 cluster should take into account the levels of availability and scalability your site requires. Start by planning your cluster so that the failure of a single node will not adversely impact cluster operations. For example, when running a two-node cluster, the failure of one node leaves the one remaining node to service all clients. This could result in an unacceptable level of performance.

Within each server, the appropriate number and speed of the CPUs and memory size are all determined by several factors. These include the types of database applications being used and the number of clients connecting to the servers.

NOTE: Certain restrictions apply to the server models and server configurations that are supported by the Compaq Parallel Database Cluster. For a current list of PDC/O2000-certified servers and details on supported configurations, refer to the *Compaq Parallel Database Cluster Model PDC/D2000 Certification Matrix for Windows 2000.* This document is available on the Compaq website at

www.compaq.com/solutions/enterprise/ha-pdc.html

Planning Shared Storage Components for Redundant Fibre Channel Fabrics

Several key components make up the shared storage subsystem for the PDC/O2000. Each redundant Fibre Channel Fabric in a PDC/O2000 uses these hardware components:

- Two or more Compaq StorageWorks 64-bit/66-MHz Fibre Channel Host Adapters or Compaq StorageWorks Fibre Channel Host Bus Adapter/Ps (Fibre Host Adapters) in each node
- Two or more Compaq StorageWorks Fibre Channel SAN Switches (Fibre Channel SAN Switches)

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- One or more Compaq StorageWorks RAID Array 4000s (RA4000 Arrays) or Compaq StorageWorks RAID Array 4100s (RA4100 Arrays)
- Two single-port Compaq StorageWorks RAID Array 4000 Controllers (RA4000 Array Controllers) installed in each RA4000/RA4100 Array. Only one array controller in the RA4000/RA4100 Array is active at any one time; the other is the standby array controller.

NOTE: For more information about redundant Fibre Channel Fabrics in a PDC/O2000 cluster, see Chapter 2, "Cluster Architecture."

The Fibre Channel SAN Switches are available in 8-port and 16-port models.

To determine which Fibre Channel SAN Switch model is appropriate for a redundant Fibre Channel Fabric in your cluster, identify the total number of nodes and RA4000/RA4100 Arrays present. If the combined number of nodes and RA4000/RA4100 Arrays exceeds eight, you must use 16-port Fibre Channel SAN Switches. Also consider the possibility of future cluster growth when you select your models.

The number of RA4000/RA4100 Arrays and shared disk drives used in a PDC/O2000 depends on the amount of shared storage space required by the database, the hardware RAID levels used on the shared storage disks, and the number and storage capacity of disk drives installed in the enclosures. Refer to "Raw Data Storage and Database Size" in this chapter for more details.

NOTE: For improved I/O performance and cluster integrity, as you increase the number of nodes in a PDC/O2000 cluster, you should also increase the aggregate bandwidth of the shared storage subsystem by adding more or higher-capacity disk drives.

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Planning Shared Storage Components for Redundant Fibre Channel Arbitrated Loops

Several key components make up the shared storage subsystem for the PDC/O2000. Each redundant Fibre Channel Arbitrated Loop (FC-AL) in a PDC/O2000 uses these hardware components:

- Two or more Fibre Host Adapters in each node
- Two or more Compaq StorageWorks Storage Hubs (Storage Hubs) or Compaq StorageWorks FC-AL Switches (FC-AL Switches)
- One or more RA4000 Arrays or RA4100 Arrays
- Two single-port RA4000 Array Controllers installed in each RA4000/RA4100 Array. Only one array controller in the RA4000/RA4100 Array is active at any one time; the other is the standby array controller.

NOTE: For more information about redundant Fibre Channel Arbitrated Loops (FC-ALs) in a PDC/O2000 cluster, see Chapter 2, "Cluster Architecture."

The FC-AL Switches are available in an 8-port model that can be expanded to 11 ports. The Storage Hubs are available in 7-port and 12-port models.

To determine which FC-AL Switch or Storage Hub model is appropriate for a redundant FC-AL in your cluster, identify the total number of nodes and RA4000/RA4100 Arrays connected to that redundant FC-AL. For FC-AL Switches, if the combined number of nodes and arrays exceeds eight, you must use 11-port FC-AL Switches. For Storage Hubs, if the combined number of nodes and arrays exceeds seven, you must use Storage Hub 12s. Also consider the possibility of future cluster growth when you select your models.

The number of RA4000/RA4100 Arrays and shared disk drives used in a PDC/O2000 depends on the amount of shared storage space required by the database, the hardware RAID levels used on the shared storage disks, and the number and storage capacity of disk drives installed in the enclosures. Refer to "Raw Data Storage and Database Size" in this chapter for more details.

NOTE: For improved I/O performance and cluster integrity, as you increase the number of nodes in a PDC/O2000 cluster, you should also increase the aggregate bandwidth of the shared storage subsystem by adding more or higher-capacity disk drives.

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Planning Cluster Interconnect and Client LAN Components

PDC/O2000 clusters running Oracle8*i* Parallel Server can use a redundant or non-redundant Ethernet cluster interconnect. Redundant cluster interconnects are recommended because they provide fault tolerance along the entire cluster interconnect path.

Planning an Ethernet Cluster Interconnect

NOTE: Refer to the technical white paper *Supported Ethernet Interconnects for Compaq Parallel Database Clusters Using Oracle Parallel Server* for detailed information about configuring redundant Ethernet cluster interconnects. This document is available at

www.compaq.com/support/techpubs/whitepapers

Before installing an Ethernet cluster interconnect in a PDC/O2000 cluster, review these planning considerations:

- Whether to use a redundant or non-redundant Ethernet cluster interconnect. A redundant Ethernet cluster interconnect is recommended because it provides fault tolerance across the cluster interconnect.
- Whether to use two Ethernet switches or two Ethernet hubs for the cluster interconnect. If your cluster will contain or grow to three or more nodes, you must use two Ethernet switches.
- Whether to use two dual-port Ethernet adapters in each node that will connect to both the cluster interconnect and the client LAN or to use separate single-port adapters for the Ethernet cluster interconnect and the client LAN.

Planning the Client LAN

Every client/server application requires a local area network (LAN) over which client machines and servers communicate. In the case of a cluster, the hardware components of the client LAN are no different than in a stand-alone server configuration.

In keeping with the redundant architecture of the cluster interconnect, you may choose to install a redundant client LAN, with redundant Ethernet adapters and redundant Ethernet switches or hubs.

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Planning Cluster Configurations for Redundant Fibre Channel Fabrics

Once you have investigated your requirements with respect to particular parts of the cluster (ProLiant servers, shared storage components, cluster interconnect components, client LAN components), you need to plan the configuration of the entire PDC/O2000. This section describes sample configurations for small and larger clusters using redundant Fibre Channel Fabrics.

IMPORTANT: Use the Oracle documentation identified in the front matter of this guide to obtain detailed information about planning for the Oracle software. Once the required level of performance, the size of the database, and the type of database have been determined, use this Oracle documentation to continue the planning of the cluster's physical components.

Sample Small Configuration in a Redundant Fibre Channel Fabric

Figure 4-1 shows an example of a small PDC/O2000 cluster: a two-node cluster with one RA4000/RA4100 Array in one redundant Fibre Channel Fabric.

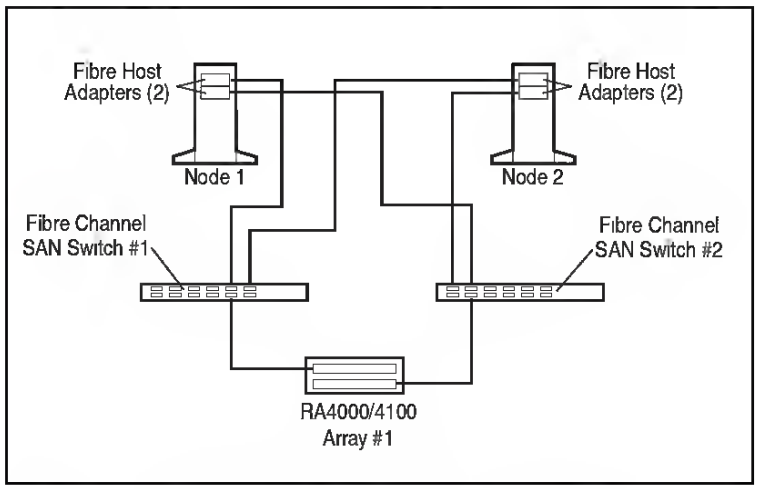

Figure 4-1. Two-node PDC/O2000 cluster with one redundant Fibre Channel Fabric and one RA4000/RA4100 Array

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The small redundant Fibre Channel Fabric cluster configuration shown in Figure 4-1 contains these key cluster components:

- Two ProLiant servers (nodes)
- Two Fibre Host Adapters in each server
- Two Fibre Channel SAN Switches
- One RA4000/RA4100 Array. Each RA4000 Array holds up to eight 1.6-inch disk drives or twelve 1-inch disk drives. Each RA4100 Array holds up to twelve 1-inch disk drives.
- Two single-port RA4000 Array Controllers in the RA4000/RA4100 Array
- Ethernet NIC adapters, cables, and Ethernet switches or hubs for the Ethernet cluster interconnect (not shown)
- Ethernet NIC adapters, switches or hubs (not shown), and cables for the client LAN

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Sample Large Configuration in a Redundant Fibre Channel Fabric

Figure 4-2 shows an example of a larger PDC/O2000 cluster: a six-node cluster with five RA4000/RA4100 Arrays in one redundant Fibre Channel Fabric.

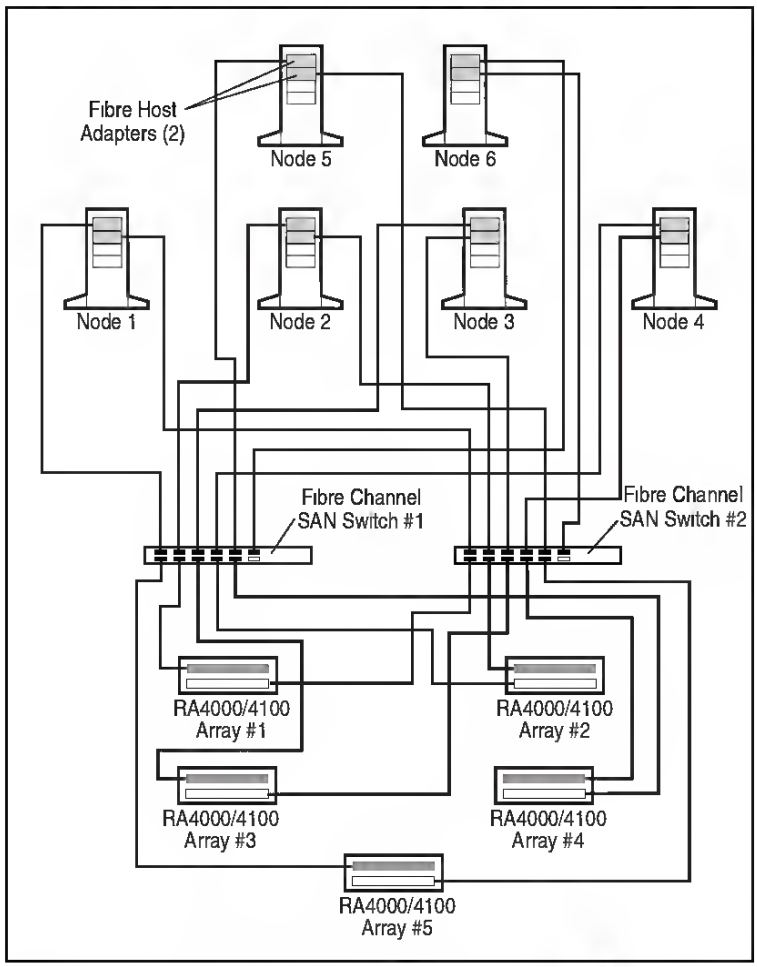

Figure 4-2. Six-node PDC/O2000 cluster with one redundant Fibre Channel Fabric and five RA4000/RA4100 Arrays

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The larger redundant Fibre Channel Fabric configuration shown in Figure 4-2 contains these key cluster components:

- Six ProLiant servers (nodes)
- Two Fibre Host Adapters in each server node
- Two Fibre Channel SAN Switches
- Five RA4000/RA4100 Arrays. Each RA4000 Array holds up to eight 1.6-inch disk drives or twelve 1-inch disk drives. Each RA4100 Array holds up to twelve 1-inch disk drives.
- Two single-port array controllers installed in each RA4000/RA4100 Array
- Ethernet NIC adapters, cables, and Ethernet switches or hubs for the Ethernet cluster interconnect (not shown)
- Ethernet NIC adapters, switches or hubs (not shown), and cables for the client LAN

This cluster configuration could be made even larger by adding a second or third redundant Fibre Channel Fabric to the PDC/O2000. Each redundant Fibre Channel Fabric or redundant FC-AL can provide its own Fibre Host Adapters and RA4000/RA4100 Arrays to the cluster without the need for adding nodes.

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Planning Cluster Configurations for Redundant Fibre Channel Arbitrated Loops

Once you have investigated your requirements with respect to particular parts of the cluster (ProLiant servers, shared storage components, cluster interconnect components, client LAN components), you need to plan the configuration of the entire PDC/O2000. This section describes sample configurations for small and large clusters using redundant FC-ALs.

IMPORTANT: Use the Oracle documentation identified in the front matter of this guide to obtain detailed information about planning for the Oracle software. Once the required level of performance, the size of the database, and the type of database have been determined, use this Oracle documentation to continue the planning of the cluster's physical components.

Sample Small Configuration in a Redundant FC-AL

Figure 4-3 shows an example of a small PDC/O2000 cluster: a two-node cluster with one RA4000/RA4100 Array in one redundant FC-AL.

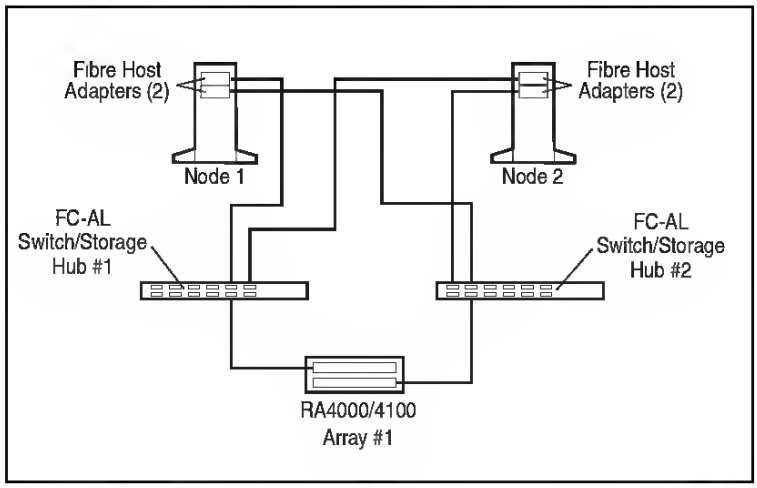

Figure 4-3. Two-node PDC/O2000 cluster with one redundant FC-AL and one RA4000/RA4100 Array

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The small redundant FC-AL configuration shown in Figure 4-3 contains these key cluster components:

- Two ProLiant servers (nodes)
- Two Fibre Host Adapters in each server
- Two Storage Hubs or FC-AL Switches
- One RA4000/RA4100 Array. Each RA4000 Array holds up to eight 1.6-inch disk drives or twelve 1-inch disk drives. Each RA4100 Array holds up to twelve 1-inch disk drives.
- Two single-port RA4000 Array Controllers in the RA4000/RA4100 Array
- Ethernet NIC adapters, cables, and Ethernet switches or hubs for the Ethernet cluster interconnect (not shown)
- Ethernet NIC adapters, switches or hubs (not shown), and cables for the client LAN

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Sample Large Configuration in a Redundant FC-AL

Figure 4-4 shows an example of a larger PDC/O2000 cluster: a six-node cluster with five RA4000/RA4100 Arrays in one redundant FC-AL.

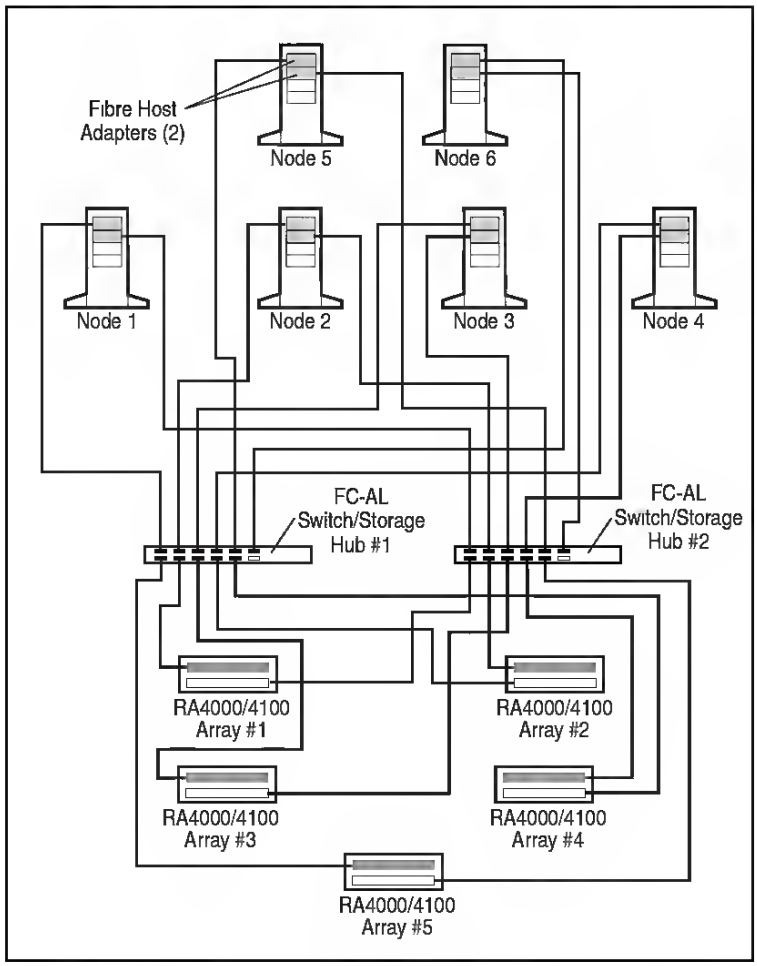

Figure 4-4. Six-node PDC/O2000 cluster with one redundant FC-AL and five RA4000/RA4100 Arrays

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The larger redundant FC-AL configuration shown in Figure 4-4 contains these key cluster components:

- Six ProLiant servers (nodes)
- Two Fibre Host Adapters in each server node
- Two Storage Hub 12s or 11-port FC-AL Switches
- Five RA4000/RA4100 Arrays. Each RA4000 Array holds up to eight 1.6-inch disk drives or twelve 1-inch disk drives. Each RA4100 Array holds up to twelve 1-inch disk drives.
- Two single-port array controllers installed in each RA4000/RA4100 Array
- Ethernet NIC adapters, cables, and Ethernet switches or hubs for the Ethernet cluster interconnect (not shown)
- Ethernet NIC adapters, switches or hubs (not shown), and cables for the client LAN

This cluster configuration could be made even larger by adding a second or third redundant FC-AL to the PDC/O2000. Each redundant FC-AL or redundant Fibre Channel Fabric can provide its own Fibre Host Adapters and RA4000/RA4100 Arrays to the cluster without the need for adding nodes.

RAID Planning

Shared storage subsystem performance is one of the most important aspects of tuning database cluster servers for optimal performance. Efforts to plan, configure, and tune a PDC/O2000 cluster should focus on getting the most out of each shared disk drive and having an appropriate number of shared drives in the cluster. When properly configured, the shared storage subsystem should not be the limiting factor in overall cluster performance.

RAID technology provides cluster servers with more consistent performance, higher levels of fault tolerance, and easier fault recovery than non-RAID systems. RAID uses redundant information stored on different disks to ensure that the cluster can survive the loss of any disk in the array without affecting the availability of data to users.

RAID also uses the technique of **striping**, which involves partitioning each drive's storage space into units ranging from a sector (512 bytes) up to several megabytes. The stripes of all the disks are interleaved and addressed in order.

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In a PDC/O2000 cluster, each node is connected to shared storage disk drives housed in RA4000/RA4100 Arrays. When planning the amount of shared storage for your cluster, you must consider the following:

- The maximum allowable number of shared storage arrays in one cluster. This maximum depends on several factors, including limits on the number of RA4000/RA4100 Arrays you can install in each redundant Fibre Channel Fabric or redundant FC-AL and how many redundant Fibre Channel Fabrics or redundant FC-ALs you plan to install in the cluster.
- The number of redundant Fibre Channel Fabrics or redundant FC-ALs allowed in a cluster, in turn, depends upon the maximum number of Fibre Host Adapters that can be installed in the ProLiant server model you will be using. Refer to the server documentation for this information.
- The appropriate number of shared storage arrays in a cluster is determined by the performance requirements of your cluster.

Refer to "Planning Shared Storage Components for Redundant Fibre Channel Fabrics" and "Planning Shared Storage Components for Redundant Fibre Channel Arbitrated Loops" in this chapter for more information.

The PDC/O2000 implements RAID at the hardware level, which is faster than software RAID. When you implement RAID on shared storage arrays, you use the hardware RAID to perform such functions as making copies of the data or calculating checksums. Use the Compaq Array Configuration Utility to implement RAID on your logical disks.

NOTE: Do not use the software RAID offered by the operating system to configure your shared storage disks.

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Supported RAID Levels

RAID provides several fault-tolerant options to protect your cluster's shared data. However, each RAID level offers a different mix of performance, reliability, and cost.

The RA4000/RA4100 Array and its RA4000 Array Controllers support these RAID levels:

- RAID 0
- RAID 0+1
- RAID I
- RAID 4
- RAID 5

NOTE: RAID 0 does not provide the fault tolerance feature of other RAID levels.

For RAID level definitions and information about configuring hardware RAID, refer to the following:

- Refer to the information about RAID configuration contained in the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.
- Refer to the Compaq white paper *Configuring Compaq RAID Technology for Database Servers*, #ECG 0I I/0598, available at the Compaq website at

  www.compaq.com
- Refer to the various white papers on Oracle8*i*, which are available at the Compaq *ActiveAnswers*™ website at

  www.compaq/activeanswers

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Raw Data Storage and Database Size

Raw data storage is the amount of storage available before any RAID levels have been configured. It is called raw data storage because RAID volumes require some overhead. The maximum size of a database stored in a RAID system will always be less than the amount of raw data storage available.

To calculate the amount of raw data storage in a PDC/O2000 cluster, determine the total amount of shared storage space available to the cluster. To do this, you need to know the following:

- The number of RA4000/RA4100 Arrays in the cluster
- The number and storage capacities of the physical drives installed in each RA4000/RA4100 Array

Add together the planned storage capacity of all RA4000/RA4100 Arrays to calculate the total amount of raw data storage in the PDC/O2000 cluster. The maximum amount of raw data storage in an RA4000/RA4100 Array depends on the type of physical drives you install in it. For example, using 1-inch high, 9-GB drives provides a maximum storage capacity of 108 GB per RA4000/RA4100 Array (twelve 9-GB drives). Using the 1.6-inch high, 18-GB drives provides a maximum storage capacity of 144 GB per RA4000/RA4100 Array (eight 18-GB drives).

The amount of shared disk space required for a given database size is affected by the RAID levels you select and the overhead required for indexes, I/O buffers, and logs. Consult with your Oracle representative for further details.

Selecting the Appropriate RAID Levels

Many factors affect which RAID levels you select for your cluster database. These include the specific availability, performance, reliability, and recovery capabilities required from the database. Each cluster must be evaluated individually by qualified personnel.

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The following general guidelines apply to RAID selection for a cluster with RA4000/RA4100 Arrays using Oracle8*i* Parallel Server:

- Oracle recommends that some form of disk fault tolerance be implemented in the cluster.
- In order to ease the difficulty of managing dynamic space allocation in an Oracle Parallel Server raw volume environment, Oracle recommends the creation of "spare" raw volumes that can be used to dynamically extend tablespaces when the existing datafiles approach capacity. The number of these spare raw volumes should represent from 10 to 30 percent of the total database size. To allow for effective load balancing, the spares should be spread across a number of disks and controllers. The database administrator should decide, on a case by case basis, which spare volume to use based on which volume would have the least impact on scalability (for both speedup and scaleup).

Planning the Grouping of Physical Disk Storage Space

Figure 4-5 shows how the physical storage space in one RA4000/RA4100 Array that contains eight physical disk drives might be grouped for an Oracle8*i* Parallel Server database.

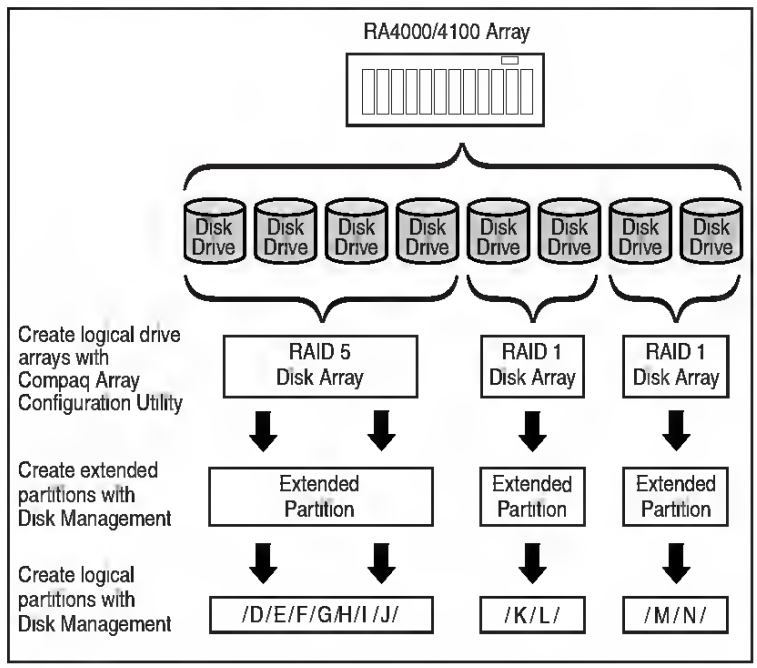

Figure 4-5. RA4000/RA4100 Array disk grouping for a PDC/O2000 cluster

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Using the Compaq Array Configuration Utility, group the RA4000/RA4100 Array disk drives into RAID disk arrays at specific RAID levels. This example shows four disk drives grouped into one RAID disk array at RAID level 5. It also shows two RAID level 1 disk arrays containing two disk drives each.

A logical drive is what you see labeled as Disk 1, Disk 2, and so on, from the Disk Management utility. For information about RAID disk arrays and logical drives, refer to the information on drive arrays in the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.

Use Disk Management to define one extended partition per RAID logical drive. Also using Disk Management, divide the extended partitions into logical partitions, each having its own drive letter. (Windows 2000 Advanced Server logical partitions are called "logical drives" in the Oracle documentation.)

IMPORTANT: To performing partitioning, all required drivers must already be installed for each server. For information about drivers, refer to the *Compaq Parallel Database Cluster Model PDC/D2000 Certification Matrix for Windows 2000.*

Disk Drive Planning

Nonshared Disk Drives

Nonshared disk drives, or local storage, operate the same way in a cluster as they do in a single-server environment. These drives can be in the server drive bays or in an external storage enclosure. As long as they are not accessible by multiple servers, they are considered nonshared.

Treat nonshared drives in a clustered environment as you would in a non-clustered environment. In most cases, some form of RAID is used to protect the drives and aid in restoration of a failed drive. Since the Oracle Parallel Server application files are stored on these drives, it is recommended that you use hardware RAID.

Hardware RAID is the recommended solution for RAID configuration because of its superior performance. For the PDC/O2000, hardware RAID for nonshared drives can be implemented with a Compaq SMART-2 controller or by using dedicated RA4000/RA4100 Arrays for nonshared storage.

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Shared Disk Drives

Shared disk drives are contained in the RA4000/RA4100 Arrays and are accessible to each node in the PDC/O2000.

If a logical drive is configured with a RAID level that does not support fault tolerance (for example, RAID 0), then the failure of the shared disk drives in that logical drive will disrupt service to all Oracle databases that are dependent on that disk drive. See "Selecting the Appropriate RAID Levels" earlier in this chapter.

As with other types of failures, Compaq Insight Manager monitors the status of shared disk drives and will mark a failed drive as "Failed."

Network Planning

Windows 2000 Advanced Server Hosts Files for an Ethernet Cluster Interconnect

When an Ethernet cluster interconnect is installed between cluster nodes, the Compaq operating system dependent modules (OSDs) require a unique entry in the hosts and lmhosts files located at %SystemRoot%\system32\drivers\etc for each network port on each node.

Each node needs to be identified by the IP address assigned to the Ethernet adapter port used by the Ethernet cluster interconnect and by the IP address assigned to the Ethernet adapter port used by the client LAN. The suffix "_san" stands for system area network.

The following list identifies the format of the hosts and lmhosts files for a four-node PDC/O2000 cluster with an Ethernet cluster interconnect:

```
IP address      node1
IP address      node1_san
IP address      node2
IP address      node2_san
IP address      node3
IP address      node3_san
IP address      node4
IP address      node4_san
```

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Client LAN

Physically, the structure of the client network is no different than that used for a nonclustered configuration.

To ensure continued access to the database when a cluster node is evicted from the cluster, each network client should have physical network access to all of the cluster nodes.

Software used by the client to communicate to the database must be able to reconnect to another cluster node in the event of a node eviction. For example, clients connected to cluster node1 need the ability to automatically reconnect to another cluster if cluster node1 fails.

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Chapter 5

Installation and Configuration

This chapter provides instructions for installing and configuring the Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000) for use with Oracle8*i* software.

A PDC/O2000 is a combination of several individually available products. As you set up your cluster, have the following materials available during installation. You will find references to them throughout this chapter.

- User guides for the clustered Compaq ProLiant servers
- Installation posters for the clustered ProLiant servers
- Installation guides for the cluster interconnect and client LAN interconnect adapters
- *Compaq StorageWorks RAID Array 4000 User Guide*
- *Compaq StorageWorks RAID Array 4100 User Guide*
- *Compaq StorageWorks Fibre Channel Host Bus Adapter Installation Guide* or *Compaq StorageWorks 64-Bit/66 MHz Fibre Channel Host Adapter Installation Guide*
- *Compaq StorageWorks Storage Hub 7 Installation Guide*
- *Compaq StorageWorks Storage Hub 12 Installation Guide*
- *Compaq StorageWorks Fibre Channel SAN Switch 8 Installation and Hardware Guide*
- *Compaq StorageWorks Fibre Channel SAN Switch 16 Installation and Hardware Guide*

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- *Compaq StorageWorks Fibre Channel SAN Switch Management Guide*
- Compaq SmartStart Installation poster
- Compaq SmartStart and Support Software CD
- *Microsoft Windows 2000 Advanced Server Administrator's Guide*
- Microsoft Windows 2000 Advanced Server CD with Service Pack 1 or later
- Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Microsoft Windows 2000 CD
- Oracle8*i* Enterprise Edition CD
- *Oracle8i Parallel Server Setup and Configuration Guide*
- Other documentation provided with the Oracle8*i* software

Installation Overview

The following summarizes the installation and setup of your PDC/O2000:

- Installing the hardware, including:
  - Proliant servers
  - Compaq StorageWorks Fibre Channel Host Bus Adapters or Compaq StorageWorks 64-Bit/66 Fibre Channel Host Adapters (Fibre Host Adapters)
  - Gigabit Interface Converter-Shortwave (GBIC-SW) modules
  - Compaq StorageWorks Fibre Channel SAN Switches (Fibre Channel SAN Switches) for redundant Fibre Channel Fabrics
  - Compaq StorageWorks Storage Hubs (Storage Hubs) or Compaq StorageWorks FC-AL Switches (FC-AL Switches) for redundant Fibre Channel Arbitrated Loops
  - Compaq StorageWorks RAID Array 4000s (RA4000 Arrays)
  - Compaq StorageWorks RAID Array 4100s (RA4100 Arrays)
  - Cluster interconnect and client LAN adapters
  - Ethernet hubs or switches

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- Installing and configuring operating system software, including:
  - SmartStart 4.9 or later
  - Windows 2000 Advanced Server with Service Pack 1 or later
- Installing and configuring Secure Path for Windows 2000, including:
  - Installing the Secure Path Server software
  - Installing the Secure Path Client software
  - Verifying Shared Storage Using Secure Path Manager
  - Defining Active Array controllers
- Installing and configuring the Compaq operating system dependent modules (OSDs), including:
  - Using Oracle Universal Installer to install OSDs for an Ethernet cluster interconnect
- Installing and configuring Oracle software, including:
  - Oracle8*i* Enterprise Edition with the Oracle8*i* Parallel Server Option
- Installing Object Link Manager
- Verifying the hardware and software installation, including:
  - Cluster communications
  - Access to shared storage from all nodes
  - Client access to the Oracle8*i* database
- Power distribution and power sequencing guidelines

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Installing the Hardware

Setting Up the Nodes

Physically preparing the nodes (servers) for a cluster is not very different than preparing them for individual use. You will install all necessary adapters and insert all internal hard disks. You will attach network cables and plug in SCSI and Fibre Channel cables. The primary difference is in setting up the shared storage subsystem.

Set up the hardware on one node completely, then set up the rest of the nodes identically to the first one. Do not load any software on any cluster node until all the hardware has been installed in all cluster nodes. Before loading software, read "Installing the Operating System Software and Configuring the RA4000/RA4100 Arrays" in this chapter to understand the idiosyncrasies of configuring a cluster.

IMPORTANT: With some possible exceptions, the servers in the cluster must be set up identically. The cluster components common to all nodes in the cluster must be identical, for example, the ProLiant server model, cluster interconnect adapters, amount of memory, cache, and number of CPUs must be the same for each cluster node. It also means the Fibre host adapters must be installed into the same PCI slots in each server.

While setting up the physical hardware, follow the installation instructions in your *Compaq ProLiant Server Setup and Installation Guide* and in your Compaq ProLiant Server Installation poster. When you are ready to install the Fibre Host Adapters and your cluster interconnect adapters, refer to the instructions in the pages that follow.

Installing the Fibre Host Adapters

Each redundant Fibre Channel Fabric or redundant Fibre Channel Arbitrated Loop (FC-AL) requires at least two Fibre Host Adapters in each cluster node. Install these devices as you would any other PCI adapter.

Install two Fibre Host Adapters on the same PCI bus in each server and into the same two PCI slots in each server. If you need specific instructions, see the *Compaq StorageWorks Fibre Channel Host Bus Adapter Installation Guide* or the *Compaq StorageWorks 64-Bit/66 MHz Fibre Channel Host Adapter Installation Guide*.

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Installing GBIC-SW Modules for the Fibre Host Adapters

Each Fibre Host Adapter ships with two GBIC-SW modules. Verify that one module is installed in the Fibre Host Adapter and the other in its Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch. Each end of the Fibre Channel cable connecting a Fibre Host Adapter to a Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch plugs into a GBIC-SW module.

To install GBIC-SW modules:

1. Verify that a GBIC-SW module has been installed into each Fibre Host Adapter in a server.
2. Insert a GBIC-SW module into the port for the Fibre Host Adapter on its Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch.
3. Repeat steps 1 and 2 for all other Fibre Host Adapters in the redundant FC-AL or redundant Fibre Channel Fabric.

Cabling the Fibre Host Adapters to the Storage Hubs or Switches

Each redundant Fibre Channel Fabric requires from two to four Fibre Channel SAN Switches. Each redundant FC-AL requires from two to four Storage Hubs or FC-AL Switches. The cabling from Fibre Host Adapters to the Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches is the same for active/standby (one active and one standby Fibre Host Adapter in each server) and active/active (two active Fibre Host Adapters in each server) configurations.

To cable the Fibre Host Adapters to the Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches:

1. Using Fibre Channel cables, connect Fibre Host Adapter #1 in each server to Storage Hub/Switch #1.
2. Using Fibre Channel cables, connect Fibre Host Adapter #2 in each server to Storage Hub/Switch #2.

IMPORTANT: When connecting a Fibre Channel Host Adapter to a Storage Hub or Fibre Channel SAN Switch, do not mount the Fibre Channel cables on cable management arms. Support the Fibre Channel cable so that a bend radius at the cable connector is not less than 3 inches.

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Figure 5-1 shows the Fibre Host Adapters in two servers connected to two Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches.

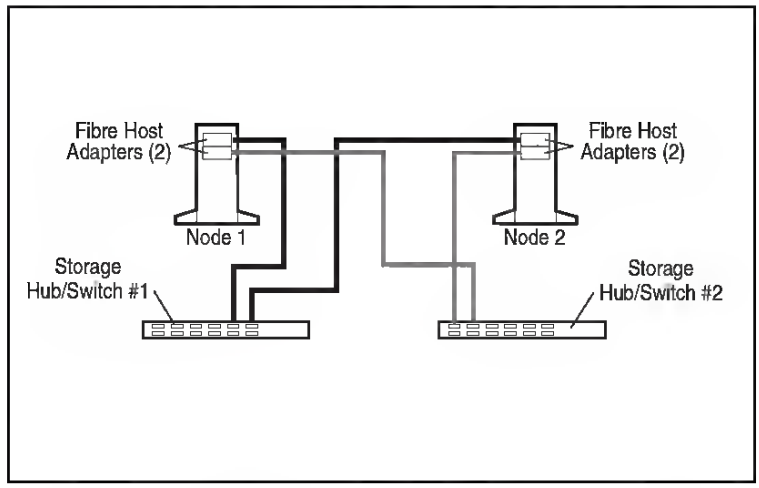

Figure 5-1. Connecting Fibre Host Adapters to Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches

For more detailed information about the Fibre Channel SAN Switch, refer to the *Compaq StorageWorks Fibre Channel SAN Switch 8 Installation and Hardware Guide*, the *Compaq StorageWorks Fibre Channel SAN Switch 16 Installation and Hardware Guide*, and the *Compaq StorageWorks Fibre Channel SAN Switch Management Guide*.

For more detailed information about the FC-AL Switch, refer to the *Compaq StorageWorks Fibre Channel Arbitrated Loop Switch (FC-AL Switch) User Guide*.

For more detailed information about the Storage Hub, refer the *Compaq StorageWorks Storage Hub 7 Installation Guide* and the *Compaq StorageWorks Storage Hub 12 Installation Guide*.

Installing the Cluster Interconnect Adapters

A PDC/O2000 running Oracle8*i* software uses an Ethernet cluster interconnect. Both redundant and non-redundant cluster interconnects are supported. However, a redundant cluster interconnect is recommended because if provides fault tolerance along the entire cluster interconnect path.

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Ethernet Cluster Interconnect Adapters

For a non-redundant Ethernet cluster interconnect, install one single-port or dual-port Ethernet adapter into each cluster node. For a redundant Ethernet cluster interconnect, install two single-port or two dual-port Ethernet adapters into each cluster node.

For recommended dual-port and single-port Ethernet adapters, see the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* at

www.compaq.com/solutions/enterprise/ha-pdc.html

If you need specific instructions on how to install an Ethernet adapter, refer to the documentation of the Ethernet adapter you are installing or refer to the user guide of the ProLiant server you are using.

Refer to the section "Cabling the Ethernet Cluster Interconnect" for more information about building an Ethernet cluster interconnect.

Installing the Client LAN Adapters

Unlike other clustering solutions, the PDC/O2000 does not allow transmission of intra-cluster communication across the client LAN. All such communication must be sent over the cluster interconnect.

Install a NIC into each cluster node for the client LAN. Configuration of the client LAN is defined by site requirements. To avoid a single point of failure in the cluster, install a redundant client LAN.

If you need specific instructions on how to install an adapter, refer to the documentation of the adapter you are installing or refer to the user guide of the ProLiant server you are using.

Setting Up the RA4000/RA4100 Arrays

Unless otherwise indicated in this guide, follow the instructions in the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide* o set up shared storage subsystem components. For example, these user guides show you how to install shared storage subsystem components for a single server; however, a PDC/O2000 contains multiple servers connected to one or more RA4000/RA4100 Arrays through redundant storage paths.

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Figure 5-2 shows two RA4000/RA4100 Arrays connected to two clustered servers through one redundant Fibre Channel Fabric or redundant FC-AL. The Fibre Channel Fabric or FC-AL is redundant because there are two paths from each node to each RA4000/RA4100 Array.

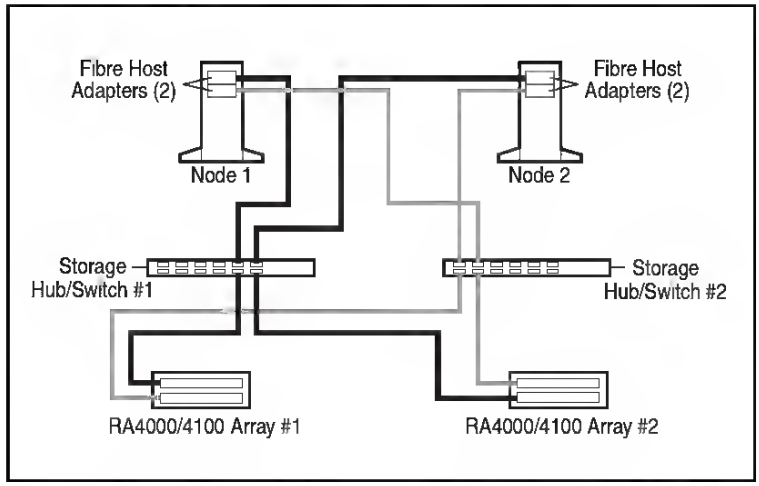

Figure 5-2. RA4000/RA4100 Arrays connected to clustered servers through one redundant Fibre Channel Fabric or redundant FC-AL

IMPORTANT: Although you can configure the RA4000/RA4100 Array with a single drive installed, it is strongly recommended for cluster configuration that all shared drives be in the RA4000/RA4100 Array before running the Compaq Array Configuration Utility.

Compaq Array Configuration Utility

The Array Configuration Utility is used to set up the hardware aspects of any drives attached to a RA4000 Array Controller, including the drives in the shared RA4000/RA4100 Arrays. The Array Configuration Utility stores the drive configuration information on the drives themselves; therefore, after you have configured the drives from one of the cluster nodes, it is not necessary to configure the drives from the other cluster node.

Before you run the Array Configuration to set up your drive arrays during the SmartStart installation, review the instructions in the "Installing the Operating System Software and Configuring the RA4000/RA4100 Arrays" section of this chapter. These instructions include clustering information that is not included in the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide.*

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For detailed information about configuring the drives using the Array Configuration Utility, see the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.

For information about configuring your shared storage subsystem with RAID, see Chapter 4, "Cluster Planning."

Installing GBIC-SW Modules for the RA4000 Array Controllers

Each RA4000/RA4100 Array contains two Compaq StorageWorks RAID Array 4000 Controllers (RA4000 Array Controllers) and ships with four GBIC-SW modules. Insert one module into an RA4000 Array Controller and the other module into a Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch. Each end of the Fibre Channel cable connecting an RA4000 Array Controller to a Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch plugs into a GBIC-SW module.

To install GBIC-SW modules:

1. Insert a GBIC-SW module into each RA4000 Array Controller in an RA4000/RA4100 Array.
2. Insert a GBIC-SW module into the correct port on each affected Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch (one module for each RA4000 Array Controller).
3. Repeat steps 1 and 2 for all other RA4000/RA4100 Arrays in the redundant Fibre Channel Fabric or redundant FC-AL.

Cabling the Storage Hubs or Switches to the RA4000 Array Controllers

You can configure a redundant Fibre Channel Fabric or a redundant FC-AL for an active/standby configuration or an active/active configuration. These types of configurations indicate the state of the Fibre Host Adapters in each node.

In an active/standby configuration, one Fibre Host Adapter in each cluster node is connected to an active RA4000 Array Controller and the other Fibre Host Adapter in each cluster node is connected to a standby RA4000 Array Controller.

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In an active/active configuration, both Fibre Host Adapters in each node are connected to an active array controller. The number of array controllers each Fibre Host Adapter is connected to depends on the number of RA4000/RA4100 Arrays in the redundant Fibre Channel Fabric or redundant FC-AL. For more information, see Chapter 2, "Cluster Architecture."

In a PDC/O2000, each RA4000/RA4100 Array has two RA4000 Array Controllers, one active and one standby. In some RA4000/RA4100 Arrays, the top RA4000 Array Controller defaults to be the active array controller and in other cases the bottom RA4000 Array Controller defaults to be the active array controller. This default can be changed using Secure Path Manager.

NOTE: RA4000/RA4100 Arrays are available in rack and tower models. RA4000 Array Controllers in rack models are located in top rear and bottom rear slots; in tower models, the array controllers are located in right rear and left rear slots. The right rear and left rear slots in tower models correspond to the top and bottom slots, respectively, in rack models. The examples in this guide show the array controller locations in rack models.

Cabling an Active/Standby Configuration

In an active/standby configuration, Storage Hub/Switch #1 connects to active RA4000 Array Controllers and Storage Hub/Switch #2 connects to standby RA4000 Array Controllers. The cabling instructions are the same for any number of RA4000/RA4100 Arrays.

NOTE: When defining the active array controllers as instructed later in this chapter, make the top array controller in each RA4000/RA4100 Array the active controller.

To cable the Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches to the RA4000 Array Controllers in an active/standby configuration:

1. Using Fibre Channel cables, connect Storage Hub/Switch #1 to the top (active) RA4000 Array Controller in each RA4000/RA4100 Array.
2. Using Fibre Channel cables, connect Storage Hub/Switch #2 to the bottom (standby) RA4000 Array Controller in each RA4000/RA4100 Array.

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Figure 5-3 shows two Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches connected to the RA4000 Array Controllers in two RA4000/RA4100 Arrays.

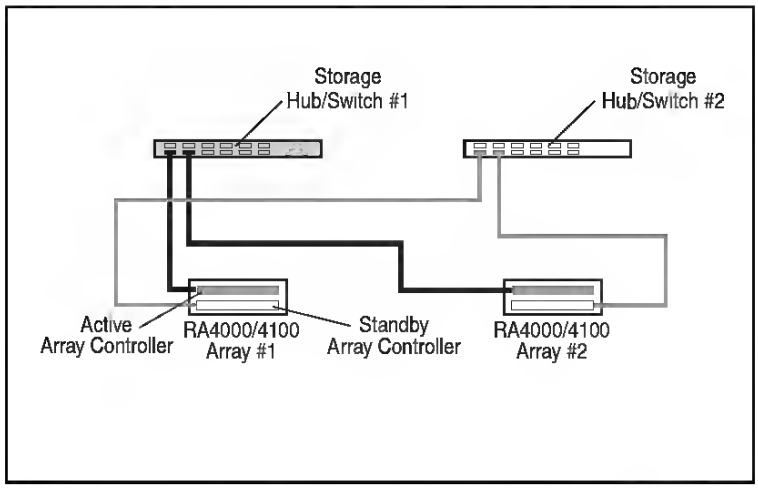

Figure 5-3. Cabling Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches to RA4000 Array Controllers in an active/standby configuration

Cabling an Active/Active Configuration

In an active/active configuration, each Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch is connected to active and standby RA4000 Array Controllers.

You can cable the Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches to the RA4000 Array Controllers using one of two methods. The differences between the two methods are the location of the active array controllers in the RA4000/RA4100 Arrays and the configuration of the Fibre Channel cables that connect the Storage Hubs or switches to the array controllers.

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Table 5-1 summarizes the active/active cabling methods. Select the method that is best for your site.

Table 5-1
Active/Active Cabling Methods

Method	Active Array Controller Location	Advantage	Disadvantage
1	Top array controller slot	Consistency in active array controller definition. All active array controllers are defined to be in the top array controller slot in each RA4000/RA4100 Array.	Cabling is more complex than for method 2. Some cables from each Storage Hub connect to the top array controller in each RA4000/RA4100 Array, and some cables from each Storage Hub or FC-AL Switch connect to the bottom array controller in each RA4000/RA4100 Array.
2	Top array controller slot in odd-numbered RA4000/RA4100 Arrays Bottom array controller slot in even-numbered RA4000/RA4100 Arrays	Consistency in cabling. All cables from Storage Hub/Switch #1 connect to the top array controller in each RA4000/RA4100 Array. All cables from Storage Hub/Switch #2 connect to the bottom array controller in each RA4000/RA4100 Array.	Defining active array controllers is more complex than for method 1. The active array controller must be defined as the top array controller slot in some RA4000/RA4100 Arrays and as the bottom array controller slot in other RA4000/RA4100 Arrays.

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Figure 5-4 shows an example of using method 1 cabling to connect two Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches to RA4000 Array Controllers in two RA4000/RA4100 Arrays.

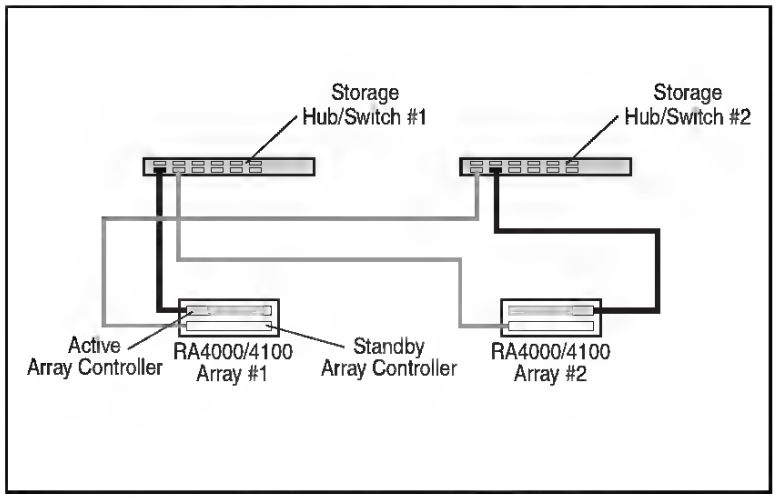

Figure 5-4. Method 1: cabling an active/active configuration with two RA4000/RA4100 Arrays

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Figure 5-5 shows an example of using method 2 cabling to connect two Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches to RA4000 Array Controllers in two RA4000/RA4100 Arrays.

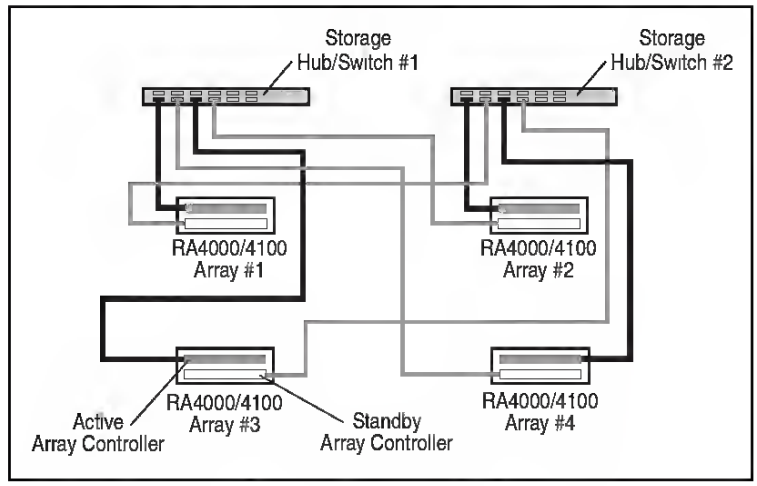

Figure 5-5. Method 2: cabling an active/active configuration with two RA4000/RA4100 Arrays

NOTE: When defining the active array controllers as instructed later in this chapter, for method 1 cabling make the top array controller in each RA4000/RA4100 Array the active controller. For method 2 cabling, make the top array controller in odd-numbered RA4000/RA4100 Arrays the active controller; make the bottom array controller in even-numbered RA4000/RA4100 Arrays the active controller.

To cable the Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches to the RA4000 Array Controllers in an active/active configuration:

1. Using Fibre Channel cables, connect Storage Hub/Switch #1 to the active RA4000 Array Controller in odd-numbered RA4000/RA4100 Arrays (RA4000/RA4100 Array #1, RA4000/RA4100 Array #3, and RA4000/RA4100 Array #5).
2. Using Fibre Channel cables, connect Storage Hub/Switch #1 to the standby RA4000 Array Controller in even-numbered RA4000/RA4100 Arrays (RA4000/RA4100 Array #2 and RA4000/RA4100 Array #4).
3. Using Fibre Channel cables, connect Storage Hub/Switch #2 to the active RA4000 Array Controller in even-numbered RA4000/RA4100 Arrays.
4. Using Fibre Channel cables, connect Storage Hub/Switch #2 to the standby RA4000 Array Controller in odd-numbered RA4000/RA4100 Arrays.

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Installing Additional Redundant Fibre Channel Fabrics

At this point, you have installed the hardware for one redundant Fibre Channel Fabric or one redundant FC-AL. To add a second redundant Fibre Channel Fabric to the PDC/O2000, install another set of the hardware required for one redundant Fibre Channel Fabric, including:

- Two or more Fibre Host Adapters in each server
- Two or more Fibre Channel SAN Switches
- Fibre Channel cables connecting the Fibre Host Adapters to the Fibre Channel SAN Switches
- One or more RA4000/RA4100 Arrays
- Fibre Channel cables connecting the Fibre Channel SAN Switches to the RA4000/RA4100 Arrays
- GBIC-SW modules for Fibre Host Adapters, Fibre Channel SAN Switches, and RA4000 Array Controllers

Installing Additional Redundant FC-ALs

To add a second redundant FC-AL to the PDC/O2000, install another set of the hardware required for one redundant FC-AL, including:

- Two or more Fibre Host Adapters in each server
- Two or more Storage Hubs or FC-AL Switches
- Fibre Channel cables connecting the Fibre Host Adapters to the Storage Hubs or FC-AL Switches
- One or more RA4000/RA4100 Arrays
- Fibre Channel cables connecting the Storage Hubs or FC-AL Switches to the RA4000/RA4100 Arrays
- GBIC-SW modules for Fibre Host Adapters, Storage Hubs or FC-AL Switches, and RA4000 Array Controllers

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Cabling the Ethernet Cluster Interconnect

A PDC/O2000 running Oracle8*i* software uses an Ethernet cluster interconnect.

The following components are used in a non-redundant Ethernet cluster interconnect:

- One Ethernet adapter in each cluster node
- Ethernet cables and a switch or hub
  - For two-node PDC/O2000 clusters, you can either use one Ethernet crossover cable or one 100-Mbit/second Ethernet switch or hub and standard Ethernet cables to connect the two servers.
  - For PDC/O2000 clusters with three or more nodes, you use one 100-Mbit/second Ethernet switch and standard Ethernet cables to connect the servers.

The following components are used in a redundant Ethernet cluster interconnect:

- Two Ethernet adapters in each cluster node
- Ethernet cables and switches or hubs
  - For two-node PDC/O2000 clusters, you can use two 100-Mbit/sec Ethernet switches or hubs with cables to connect the servers.
  - For PDC/O2000 clusters with three or more nodes, you use two 100-Mbit/sec Ethernet switches connected by Ethernet cables to a separate Ethernet adapter in each server.

NOTE: In a redundant Ethernet cluster configuration, one Ethernet crossover cable must be installed between the two Ethernet switches or hubs that are dedicated to the cluster interconnect.

To connect two nodes in a non-redundant Ethernet cluster interconnect using an Ethernet crossover cable:

1. In both nodes, install the Ethernet crossover cable into the port on the Ethernet adapter that is designated for the Ethernet cluster interconnect.
2. If you have a dual-port Ethernet adapter in each node, you can use the second (lower) port on each to connect to a client LAN hub or switch.

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Figure 5-6 shows the non-redundant Ethernet cluster interconnect components used in a two-node PDC/O2000 cluster. These components include a dual-port Ethernet adapter in each node. The top port on each adapter connects by Ethernet crossover cable to the top port on the adapter in the other node. The bottom port on each adapter connects by Ethernet cable to the client LAN switch or hub.

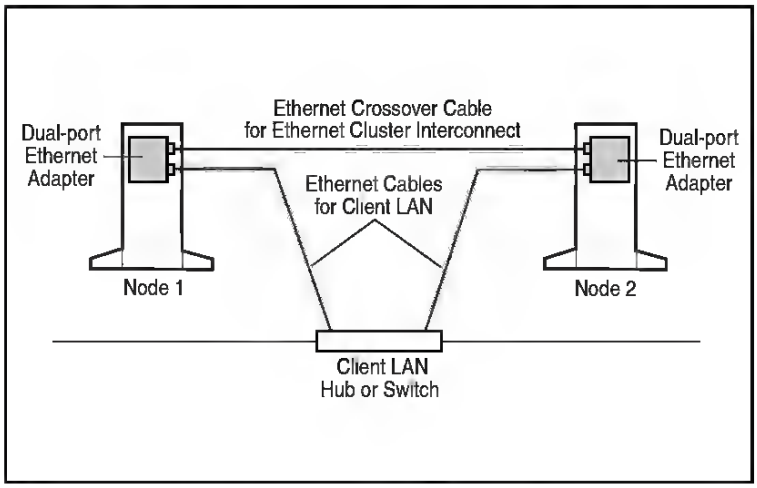

Figure 5-6. Non-redundant Ethernet cluster interconnect using a crossover cable

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To connect two or more nodes in a non-redundant Ethernet cluster interconnect:

1. Install a standard Ethernet cable between an Ethernet adapter in one node and one Ethernet hub or switch.
2. Repeat step 1 for every other node in the cluster.

Figure 5-7 shows another option for a non-redundant Ethernet cluster interconnect in a two-node PDC/O2000 cluster. These include an Ethernet adapter in each node connected by Ethernet cables to an Ethernet switch or hub.

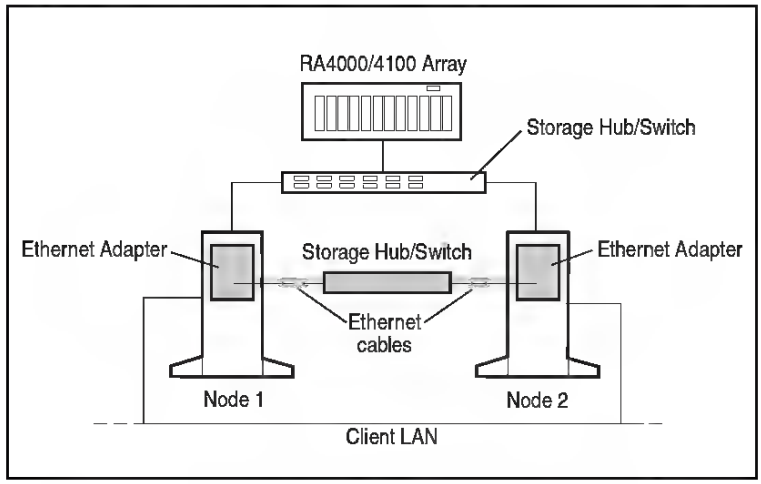

Figure 5-7. Non-redundant Ethernet cluster interconnect using an Ethernet switch or hub

To connect two or more nodes in a redundant Ethernet cluster interconnect:

1. Insert the ends of two Ethernet cables into two Ethernet adapter ports designated for the cluster interconnect.
2. Connect the other end of one Ethernet cable to an Ethernet hub or switch. Connect the other end of the second Ethernet cable to the second Ethernet hub or switch.
3. Repeat steps 1 and 2 for all other nodes in the cluster.
4. Install one crossover cable between the Ethernet hubs or switches.

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Figure 5-8 shows the redundant Ethernet cluster interconnect components used in a PDC/O2000 with two or more nodes.

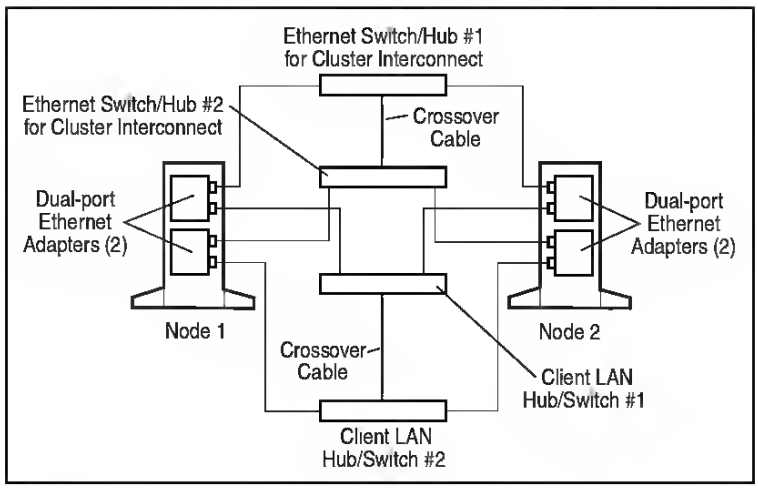

Figure 5-8. Redundant Ethernet cluster interconnect for a two-node PDC/O2000 cluster

These components include two dual-port Ethernet adapters in each cluster node. The top port on each adapter connects by Ethernet cable to one of two Ethernet switches or hubs provided for the cluster interconnect. The bottom port on each adapter connects by Ethernet cable to the client LAN for the cluster. A crossover cable is installed between the two Ethernet switches or hubs used in the Ethernet cluster interconnect.

For clusters of three or more nodes using a redundant Ethernet cluster interconnect, Compaq requires that you use two Ethernet 100-Mbit/sec switches to maintain good network performance across the cluster. If there are only two nodes in a cluster, you can use either Ethernet hubs or switches and standard Ethernet cables to connect the nodes.

For more information on configuring Ethernet connections in a redundant or non-redundant cluster interconnect, including enabling failover from one Ethernet path to another, see *Supported Ethernet Interconnects for Compaq Parallel Database Clusters Using Oracle Parallel Server* at

www.compaq.com/support/techpubs/whitepapers

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Cabling the Client LAN

You can use any TCP/IP network to connect to a client LAN. The following procedure contains instructions for cabling an Ethernet client LAN.

To cable an Ethernet client LAN:

1. Insert one end of an Ethernet cable into an Ethernet adapter port designated for the client LAN in a cluster node.

   If you are using a recommended dual-port Ethernet adapter for the cluster interconnect, connect the client LAN to the empty port.

   If you are using a recommended single-port adapter for the cluster interconnect, connect the client LAN to the port on the embedded adapter or to another single-port Ethernet adapter.

2. Connect the node to the client LAN by inserting the other end of the client LAN Ethernet cable to a port in the Ethernet hub or switch.

3. Repeat steps 1 and 2 for all other cluster nodes.

Redundant Client LAN

If you elect to install an Ethernet client LAN, a redundant client LAN requires two single-port Ethernet adapters or one dual-port Ethernet adapter in each cluster node. It also requires two Ethernet hubs or switches, and one Ethernet crossover cable must be installed between the Ethernet hubs or switches. Installing redundant crossover cables directly between the nodes is not supported.

For information on configuring Ethernet connections in a redundant client LAN, including enabling failover from one Ethernet path to another, see *Supported Ethernet Interconnects for Compaq Parallel Database Clusters Using Oracle Parallel Server* at

www.compaq.com/support/techpubs/whitepapers

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Installing the Operating System Software and Configuring the RA4000/RA4100 Arrays

You will follow an automated procedure using Compaq SmartStart to install the operating system software and configure the shared storage disks on the RA4000/RA4100 Arrays.

Guidelines for Clusters

Installing clustering software requires several specific steps and guidelines that might not be necessary when installing software on a single server. Be sure to read and understand the following items **before** proceeding with the specific software installation steps in "Automated Installation Steps."

- Because a PDC/O2000 contains multiple servers, have sufficient software licensing rights to install Windows NT Server software applications on each server.
- Be sure your servers, adapters, hubs, and switches are installed and cabled before you install the software.
- Power on the cluster as instructed later in this chapter in "Power Distribution and Power Sequencing Guidelines."
- SmartStart runs the Compaq Array Configuration Utility, which is used to configure the drives in the RA4000/RA4100 Arrays. The Array Configuration Utility stores the drive configuration information on the drives themselves. After you have configured the shared drives from one of the cluster nodes, it is not necessary to configure the drives from the other cluster nodes.

  When the Array Configuration Utility runs on the first cluster node, configure the shared drives in the RA4000/RA4100 Array. When SmartStart runs the utility on the other cluster nodes, you will be presented the information on the shared drives that was entered when the Array Configuration Utility was run on the first node. Accept the information as presented and continue.

  NOTE: Local drives on each cluster node still need to be configured.

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- When you set up an Ethernet cluster interconnect, be sure to select TCP/IP as the network protocol. The Ethernet cluster interconnect should be on its own subnet.

IMPORTANT: The IP addresses of the Ethernet cluster interconnect must be static, not dynamically assigned by DHCP.

- Be sure to set up unique IP addresses and node names for each node in the hosts and lmhosts files at %SystemRoot%\system32\drivers\etc.
  - For an Ethernet cluster interconnect, one IP address and node name is for the cluster interconnect, and the other IP address and node name is for the client LAN. Both entries are required for each node in the cluster.
  - After setting up these file entries, be sure to restart the node so it picks up the correct IP addresses.
- After you have installed Windows 2000 Advanced Server, run Disk Management on each node to verify you can see the shared storage subsystem resources on all RA4000/RA4100 Arrays and select **Commit Changes** in Disk Management. Restart all nodes.

Automated Installation Using SmartStart

CAUTION: Automated installation using SmartStart assumes that it is being installed on new servers. If there is any existing data on the servers, it will be destroyed.

You will need the following during SmartStart installation:

- SmartStart and Support Software CD 4.9 or later
- Microsoft Windows 2000 Advanced Server with Service Pack 1 or later
- SmartStart Installation poster
- Server Profile diskette

Cluster-Specific SmartStart Installation

The SmartStart Installation poster describes the general flow of configuring and installing software on a single server. The installation for a PDC/O2000 will be very similar.

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The one difference is that through the Array Configuration Utility, SmartStart gives you the opportunity to configure the shared drives on all servers. For cluster configuration, you should configure the drives on the first server, then accept the same settings for the shared drives when given the option on the other servers.

Automated Installation Steps

You will perform the following automated installation steps to install operating system software on every node in the cluster.

1. Power up the following cluster components in this order:
   - ❑ RA4000/RA4100 Arrays
   - ❑ Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches
   - ❑ Ethernet hubs or switches
2. Power up a cluster node and put the SmartStart and Support Software CD into the CD-ROM drive.
3. Select the **Assisted Integration** installation path.
4. When prompted, insert the Server Profile diskette into the floppy disk drive.
5. Select **Windows 2000 Advanced Server** as the operating system.
6. Continue with the Assisted Integration installation. Windows 2000 Advanced Server is installed as part of this process.

   NOTE: For clustered servers, take the default for Automatic Server Recovery (ASR) and select **standalone** as the server type.

   NOTE: When prompted to use the Array Configuration Utility, it is only necessary to configure the shared drives during the first node's setup. When configuring the other nodes, the utility shows the results of the shared drives configured during the first node's setup.

   NOTE: Do not install Microsoft Cluster Server.

7. From **Start**, select **Settings** and then select **Network and Dial-up Connections**. Select the first connection and right click. Select **Properties**. Select the Internet Protocol (TCP/IP) box and click **OK.**
8. Double-click on **TCP/IP** and the **Internet Protocol (TCP/IP) Properties** screen is displayed. Enter the IP address as appropriate for each of the port connections.

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9. Enter unique IP addresses and node names for each node in the hosts and lmhosts files located at %SystemRoot%\system32\drivers\etc. Record this information:

   - For an Ethernet cluster interconnect, one IP address and node name is for the redundant cluster interconnect, and the other IP address and node name is for the client LAN. For example, **node1** for the client LAN and **node1_san** for the cluster interconnect. (The "_san" stands for system area network.)

   Due to the complexity of Windows 2000 Advanced Server and multiple-NIC servers, you need to verify that the correct IP addresses are assigned to the correct ports/NICs and that the Ethernet cables are connected to the correct ports. If IP addresses are not assigned to the correct port, Oracle software and external programs cannot communicate over the proper network link. The next step describes how to perform this verification.

10. Verify that the IP addresses for the client LAN and cluster interconnect are correctly assigned by pinging the machine host name. (Find this name by selecting the **Network ID** tab on the **System Properties** menu in the System Control Panel.) The IP address returned by the ping utility is one of the IP addresses you specified; it is the IP address that Windows 2000 Advanced Server assigned to the client LAN.

11. If the ping command does not return the IP address you specified in the **TCP/IP Properties** dialog box for the client LAN port and you are using Service Pack 1 or later:

    a. Double-click the **Network and Dial-up Connections** icon in the Control Panel. From the **Advanced** menu, click **Advanced Settings.** A list of Ethernet connections are shown. The first on the list is the **Primary Connection.**

    b. Select all protocols in the **Show Bindings for** scroll box.

    c. Click + (plus sign) next to the TCP/IP protocol. A list of all installed Ethernet NICs appears, including the slot number and port number of each. Windows NT Server uses the NIC at the top of the list for the client LAN.

    d. Change the binding order of the NICs to put the NIC you specified for the client LAN at the top of the list. Find the client LAN NIC in the list and select it.

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e. With the client LAN NIC selected, click **Move Up** to position this NIC to the top of the list.

f. Click **OK** on the dialog box and restart the node when prompted.

IMPORTANT: Record the cluster interconnect node name, the client LAN node name, and the IP addresses assigned to them. You will need this information later when installing Compaq OSDs.

---

12. If you are installing node1, open Windows 2000 Advanced Server Disk Management to create extended disk partitions and logical partitions within the extended partitions on all RA4000/RA4100 Arrays. (If you are installing a node other than node1, skip to step 13.)

    Create all disk partitions on the RA4000/RA4100 Arrays from node1, select **Commit Changes Now** from the **Partition** menu, and restart the node.

    For more information on creating partitions, see the *Oracle8i Parallel Server Setup and Configuration Guide*.

13. If you are installing a node other than node1, open Disk Management to verify that the same shared disk resources are seen from this node as are seen from other installed nodes in the cluster. If they are not, restart the node and review the shared disk resources again.

14. Repeat steps 2 through 13 on all other cluster nodes.

15. After configuring all nodes in the cluster, verify the client LAN connections by pinging all nodes in the cluster from each cluster node. Use the client LAN node name, (for example, **node1**) with the ping command. If you are using a redundant Ethernet cluster interconnect, verify the cluster interconnect connections by using the Ethernet cluster interconnect node name (for example, **node1_san**) with the ping command.

16. Power down the cluster nodes and client LAN Ethernet switches or hubs.

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Installing Secure Path Software for Windows 2000

The Secure Path software for Windows 2000 is installed on both the server and the client. The Secure Path server software is installed on the Windows host system to which the RAID storage system is connected. TCP/IP must be installed on the host system. Secure Path software must be installed on each member of the cluster.

NOTE: Secure Path installation requires that a temporary directory be available on the system drive. For example: C:\Temp

Installing the Secure Path Server Software

To install the Secure Path Server software:

1. Insert the Compaq SANWorks Secure Path Software CD into your CD-ROM drive.
2. If you have AutoRun enabled on your server, the Secure Path setup program will start automatically. If AutoRun is not enabled, select **Run** from the **Start** menu and enter the following command:

   DRIVE_LETTER:\spinstall\setup.exe

   where *DRIVE_LETTER* is the drive letter assigned to the CD-ROM drive.
3. When the setup begins, select the destination path. Select **Secure Path Server Install** to install the required drivers and agent on your server.

   The **Server Install** option prompts you to designate clients permitted to manage the host. **Setup**, by default, lists the proper DNS name to use for accessing the local host from a client (Secure Path Manager) running on the local host.

   NOTE: Check with your System Administrator to ensure that the correct TCP/IP network configurations and protocols have been established.
4. Enter a validation password. The password must be the same for each member of the cluster.

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Installing the Secure Path Client Software

Install the Secure Path Client software on either the same Windows host system as the Secure Path Server software or any Windows workstation. The workstation must be TCP/IP-capable.

To install the Secure Path Client software:

1. Insert the Compaq SANWorks Secure Path Software CD into your CD-ROM drive.
2. If you have AutoRun enabled on your server, the Secure Path setup program will start automatically. If AutoRun is not enabled, select **Run** from the **Start** menu and enter the following command:

   DRIVE_LETTER:\spinstall\setup.exe

   where *DRIVE_LETTER* is the drive letter assigned to the CD-ROM.
3. When the setup begins, select the destination folder. Select **Secure Path Client Install** to install the Secure Path Manager software.

For more detail information on installing Secure Path software, refer to the document *Secure Path for Windows 2000 on RAID Array 4000/4100.*

Verifying Shared Disk Storage Using Secure Path Manager

Make sure you can see the same shared disk storage resources from eacb node using Secure Path Manager as you can with Disk Management.

To verify the shared storage resources from Secure Path Manager:

IMPORTANT: Run Secure Path Manager from only one cluster node at a time. Otherwise, multiple Secure Path Manager processes will try to control the same RA4000/RA4100 Arrays.

---

1. On a cluster node, click **Start**, **Programs**, and under Secure Path click **SPM**. The **Secure Path Manager (Fibre Channel)** screen is displayed.
2. The Secure Path Manager is setup in a "tree" structure with storage arrays as the first branch. Storage arrays are designated with the name "Storage System *X*"; where *X* identifies the number of storage arrays you have beginning with 0.

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3. If you double-click **"Storage System *X*",** you should get two more branches that represent the two RA4000 Array Controllers in that array. These controllers are named "ControllerA" and "ControllerB," which correspond to the Active controller and the Standby controller, respectively.
4. Once you are at the controller branch, you can identify and verify the Active controller by double-clicking on the controller with a **"+"** character next to it. When you open the controller marked with the **"+"** character, the logical drives (LUNS) for that controller are displayed. You can change the view of your logical drives by using the **View** pull-down menu.
5. Repeat steps 1 through 4 on all PDC/O2000 cluster nodes to verify that Secure Path Manager displays the same shared disk storage resources information from each node.

Defining Active Array Controllers

When a new RA4000/RA4100 Array is first installed, the top array controller should be the active controller and the bottom controller should the standby controller. You can confirm the location of the active controller by verifying that its ninth green LED is on. Over time, however, it is not uncommon for the active and standby states of the two controllers to be interchanged. Consequently, in some RA4000/RA4100 Arrays, the RA4000 Array Controller in the top array controller slot will be the active array controller and in other cases the RA4000 Array Controller in the bottom array controller slot will be the active array controller.

You need to define the correct slot location (top or bottom) for the active array controller in an RA4000/RA41000 Array according to the type of configuration you are using (active/standby or active/active). If you are using an active/active configuration, the active array controller's slot location also depends on the cabling method employed, as discussed previously in "Cabling an Active/Active Configuration." Table 5-2 provides guidelines for defining the active array controller slot location under these various configurations.

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Table 5-2
Active Array Controller Locations

Configuration	Active Array Controller Location
Active/Standby	Top array controller slot
Active/Active: Cabling Method 1	Top array controller slot
Active/Active: Cabling Method 2	Top array controller slot in odd-numbered RA4000/RA4100 Arrays Bottom array controller slot in even-numbered RA4000/RA4100 Arrays

NOTE: If Secure Path Manager indicates that the active array controllers are already located in the proper slots, you do not need to redefine their locations by performing the following procedure.

Changing the location of the active array controller changes the entire redundant Fibre Channel Fabric path or redundant FC-AL path, which includes the Fibre Host Adapter, the Storage Hub, FC-AL Switch, or Fibre Channel SAN Switch, and the RA4000 Array Controller. So, when you change the active array controller, you change the entire active Fibre Channel Fabric or FC-AL path.

To change the active Fibre Channel Fabric or FC-AL path:

IMPORTANT: Run Secure Path Manager from only one cluster node at a time. Otherwise, multiple Secure Path Manager processes will try to control the same RA4000/RA4100 Arrays.

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1. On any cluster node, click **Start**, **Programs**. Under Secure Path, click **SPM.** The **Secure Path Manager (Fibre Channel)** screen is displayed.
2. After clicking on the logical drives (LUNS) you would like to move to the other array controller, right-click the first controller and a pop-up message appears that states "Move to Other Controller." Left-click the message and the logical drives will now move to the other controller. You can also move the desired logical drives by left-clicking on the drives and keeping the left mouse button held down while dragging them to the other controller. Once you let go, the logical drives will be "dropped" onto the other controller.

   NOTE: You cannot drop logical drives (LUNs) from an array controller on one RA4000/RA4100 Array to an array controller on another RA4000/RA4100 Array.

   IMPORTANT: Wait at least 10 to 30 seconds after changing an FC-AL path in one RA4000/RA4100 Array before changing an FC-AL path in another RA4000/RA4100 Array.

3. Repeat steps 1 and 2 for every RA4000/RA4100 Array in which you need to change the active Fibre Channel Fabric or FC-AL path.

Installing Compaq OSDs

Use the Oracle Universal Installer (OUI) program to install the Compaq operating system dependent modules (OSDs) for Oracle8*i* Parallel Server. Compaq supplies a software package with the OUI that installs Compaq OSDs for an Ethernet cluster interconnect.

The OUI runs from one node in the cluster and performs the following tasks:

- Copies the OSDs to the internal hard drive of all cluster nodes.
- Sets up registry entries for file location and standard registry parameters for the OSDs on all cluster nodes.

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From one node in the cluster, the OUI installs and configures OSDs on the other nodes in the cluster, provided that:

- The servers are communicating through a local area network using a TCP/IP protocol.
- The user running the OUI program has administrator privileges on every node.

Verifying Cluster Communications

IMPORTANT: The successful completion of the OUI program depends on TCP/IP connectivity being set up correctly. It also depends on the person running the OUI having administrator access to every node in the cluster. **Before** running the OUI, verify cluster communications and the administrator privileges of the person performing the installation.

If the OSDs do not install successfully, the OUI will not offer the option to install Oracle8*i* Parallel Server.

The Compaq operating system dependent modules (OSDs) are installed from one node in the cluster (the installing node). The node on which you run the OUI program must be able to communicate with every other node in the cluster in order to copy information to all other cluster nodes.

Use the ping utility to verify that each node in the cluster can communicate with every other node.

Run the ping utility from each node in the cluster. Ping the client LAN name of every node in the cluster. The client LAN name and client LAN IP address were assigned to each cluster node while you were using SmartStart to install the operating system software.

If you are using an Ethernet cluster interconnect, a cluster interconnect name and IP address were assigned to each cluster node. Ping the Ethernet cluster interconnect name of every node in the cluster.

When using the client LAN name with the ping command, the IP address displayed by the ping utility should be the client LAN IP address. When using an Ethernet cluster interconnect name, the IP address displayed by the ping utility should be an Ethernet cluster interconnect address. If the ping utility does not return the expected IP addresses, check the entries in the hosts and lmhosts files at %SystemRoot%\system32\drivers\etc.

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For example, the command **ping node1** should return the following type of information.

Pinging node1.loc1.yoursite.com [127.0.0.1] with 32 bytes of data:

```
Reply from 127.0.0.1: bytes=32 time<10ms TTL=128
Reply from 127.0.0.1: bytes=32 time<10ms TTL=128
Reply from 127.0.0.1: bytes=32 time<10ms TTL=128
Reply from 127.0.0.1: bytes=32 time<10ms TTL=128
```

Mounting Remote Drives and Verifying Administrator Privileges

Because the OUI installs and configures OSDs on the other nodes in the cluster from the installing machine, you must first mount a drive on all remote nodes in the cluster. Remote nodes are those nodes other than the node on which the OUI is running (the installing machine).

The drive you mount should be the drive the OUI will write to, and it must be the same drive on all cluster nodes. There should be at least five megabytes of space on the remote drives.

The **net use** command can be used to mount drives on remote nodes. The person running the **net use** command must have administrator privileges. Therefore, running the **net use** command not only mounts drives on remote nodes but also verifies the administrator privileges of the installer.

Administrator privileges are required for most installation tasks, such as installing device drivers and changing registry entries. To install the OSDs, you must have administrator privileges on each node from the installing machine.

To mount drives on remote nodes, enter a **net use** command from a C: prompt on the installing machine. Enter one instance of the command for each remote cluster node. The following example mounts the C: drive on a remote node.

```
C: net use \\machine_name\C$ * /User: <admin_login >
```

The "*" results in the system prompting you for a password, and the password is not echoed. (The **Map Network Drive** option in Windows Explorer is an alternative to the **net use** command.)

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If successful, the **net use** command returns:

"The command completed successfully."

If the command is not successful, make sure the administrative shares on remote node drives are present.

Installing the Ethernet OSDs

To install the OSDs for an Ethernet cluster interconnect:

1. From the installing node, log in as a user who has administrator privileges on all nodes in the cluster. If all servers in the cluster are in the same domain, log in as a user who is a member of the Domain Administrators group. If the servers are in different domains, create a local user on each server with the same Windows Server user name and password on each node. Then make that local user a member of the local Administrators group on each node before installing the OSDs.
2. Insert the Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Microsoft Windows 2000 CD into the CD-ROM drive.

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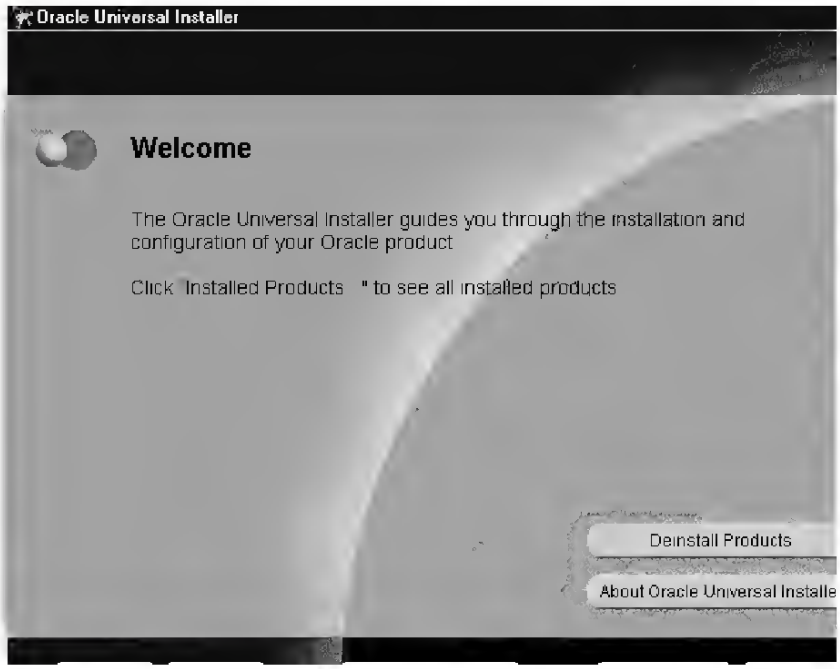
3. If autorun is enabled, the Oracle Universal Installer **Welcome** screen appears.

   If autorun is disabled, enter ***d*:\setup** at a C: prompt. Substitute the letter assigned to the CD drive for ***d***. The Oracle Universal Installer **Welcome** screen appears.

NOTE: The OUI screens presented here might indicate earlier revision levels for the OSDs.


Oracle Universal Installer
Welcome
The Oracle Universal Installer guides you through the installation and configuration of your Oracle product
Click "Installed Products" to see all installed products
Deinstall Products
About Oracle Universal Installe

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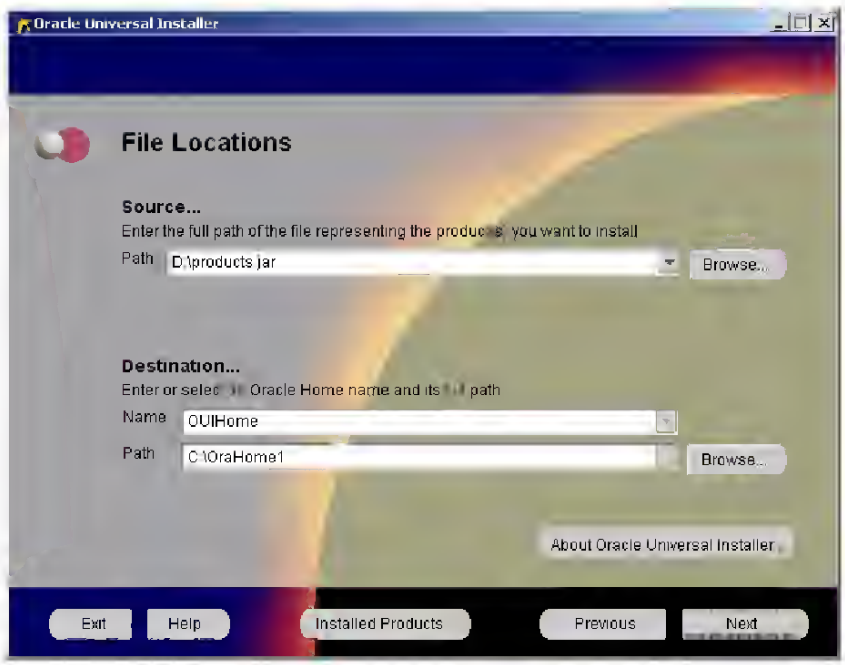
4. Click **Next** to continue. The **License** screen appears.
5. Click **Accept** to accept the terms of the license agreement. The **File Locations** screen appears.



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6. Click **Next** to continue. The **Installation Types** screen appears.

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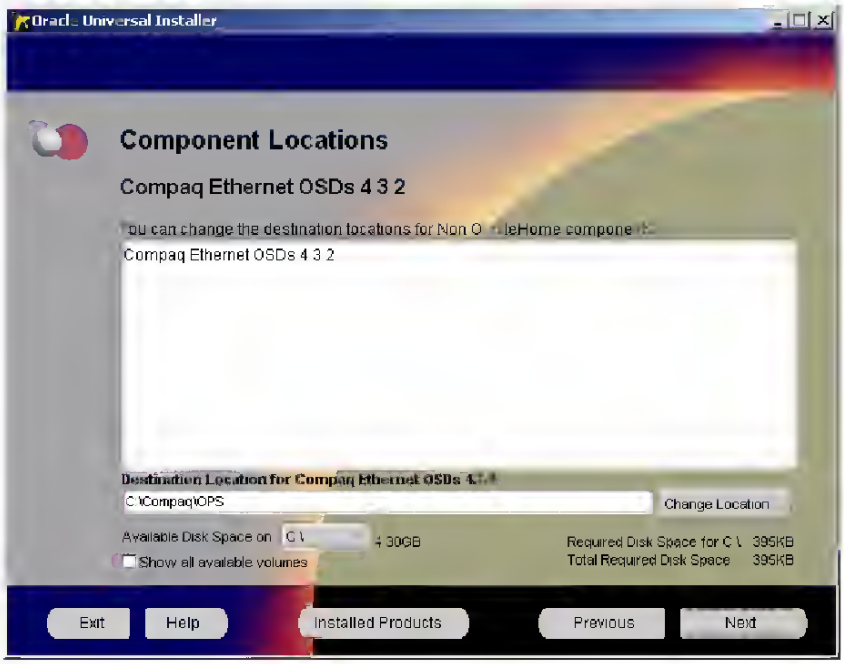
7. Select **Typical** to install the Ethernet OSDs into the default location, C:\Compaq\OPS. Skip to step 12.
8. Select **Custom** to install the Ethernet OSDs into a location of your choice. The **Component Locations** screen appears.



9. If you want to accept the default location, skip to step 13.
10. If you want to specify an alternate location and you know the exact directory path, specify it by typing over the default location and skip to step 12.

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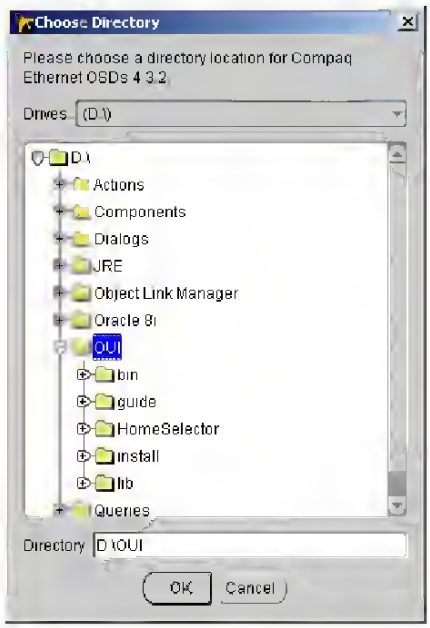
11. If you want to specify an alternate location but do not know the exact directory path, click **Change Location.** The **Choose Directory** screen appears.



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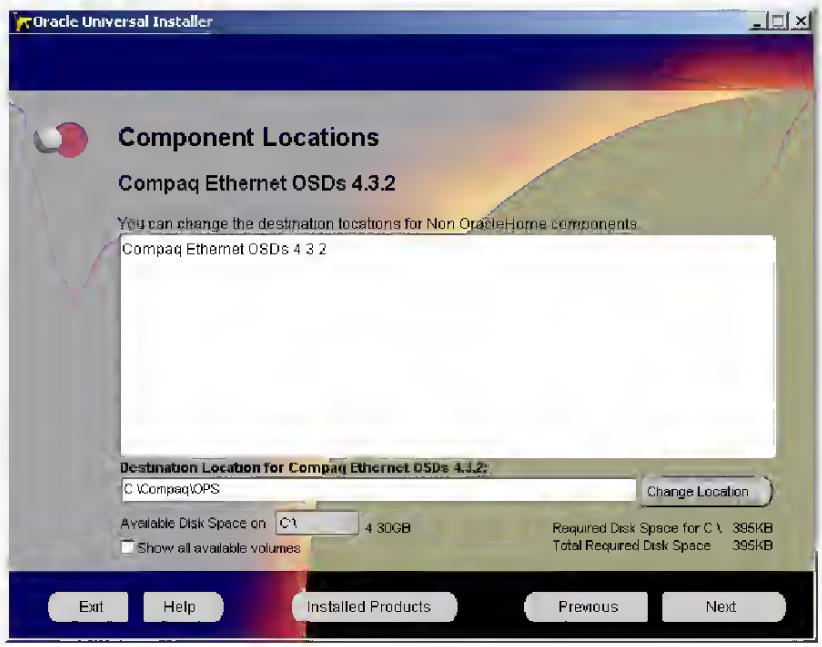
12. Browse to the location where you want to install the OSDs. Click **OK.** The **Component Locations** screen appears indicating the alternate location you specified.



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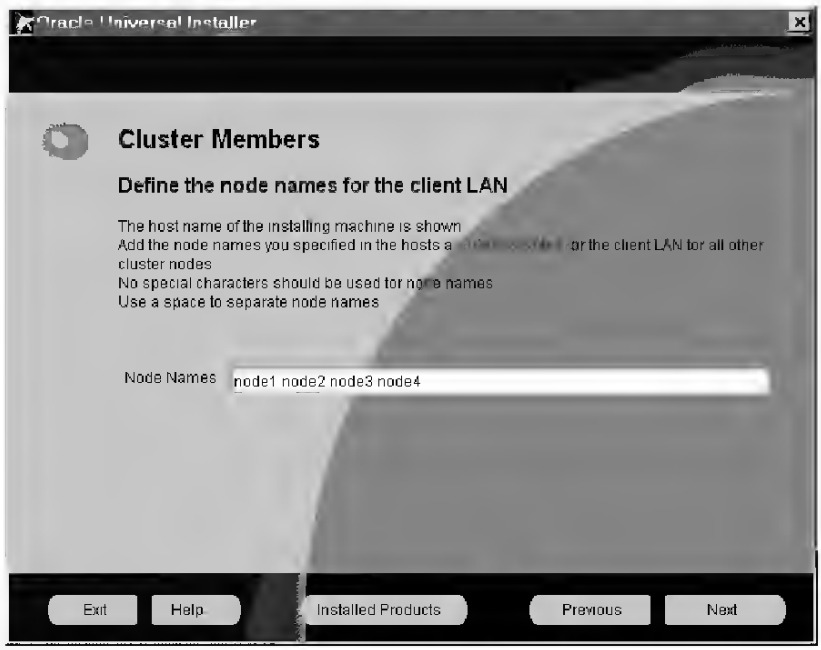
13. Click **Next** to continue. The **Cluster Members** screen appears.


Oracle Universal Installer
Cluster Members
Define the node names for the client LAN
The host name of the installing machine is shown
Add the node names you specified in the hosts a
or the client LAN for all other
cluster nodes
No special characters should be used for node names
Use a space to separate node names
Node Names
node1 node2 node3 node4
Exit
Help
Installed Products
Previous
Next

14. The **Cluster Members** screen indicates the host name of the installing machine. Define the node names for the client LAN by adding the node names you specified in the hosts and lmhosts files for the client LAN for all other cluster nodes. Do not use special characters. Use a space to separate the node names.

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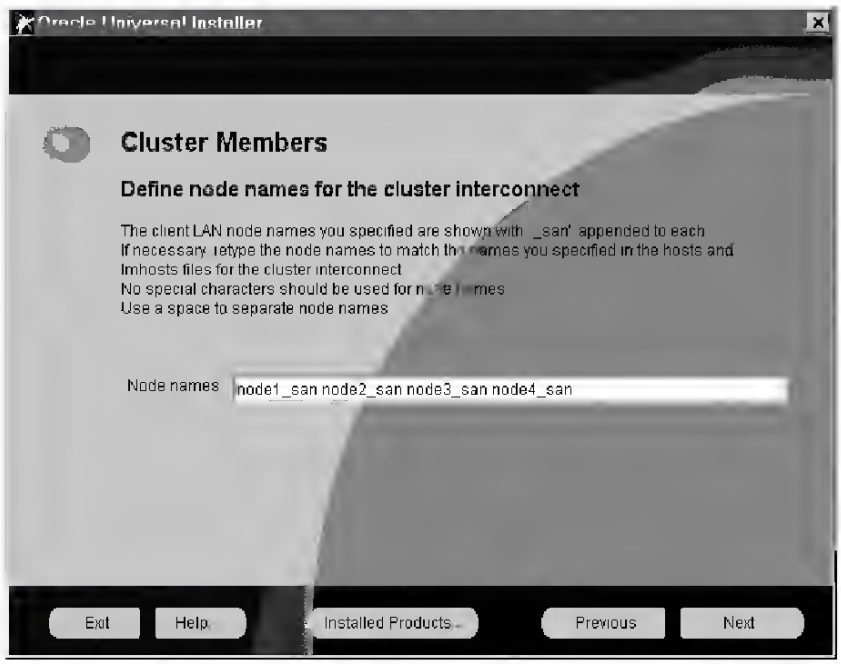
15. Click **Next** to continue. The **Cluster Members** screen reappears.


Oracle Universal Installer
Cluster Members
Define node names for the cluster interconnect
The client LAN node names you specified are shown with _san' appended to each
If necessary, retype the node names to match the names you specified in the hosts and
lmhosts files for the cluster interconnect
No special characters should be used for node names
Use a space to separate node names
Node names
node1_san node2_san node3_san node4_san
Exit
Help
Installed Products...
Previous
Next

16. The **Cluster Members** screen now shows the node names you specified on the first **Cluster Members** screen with "_san" appended to each name, indicating it as a cluster interconnect node name.

    If necessary, retype the cluster interconnect node names to match the names you entered into the hosts and lmhosts files for the Ethernet cluster interconnect. Do not use special characters. Separate the node names with a space.

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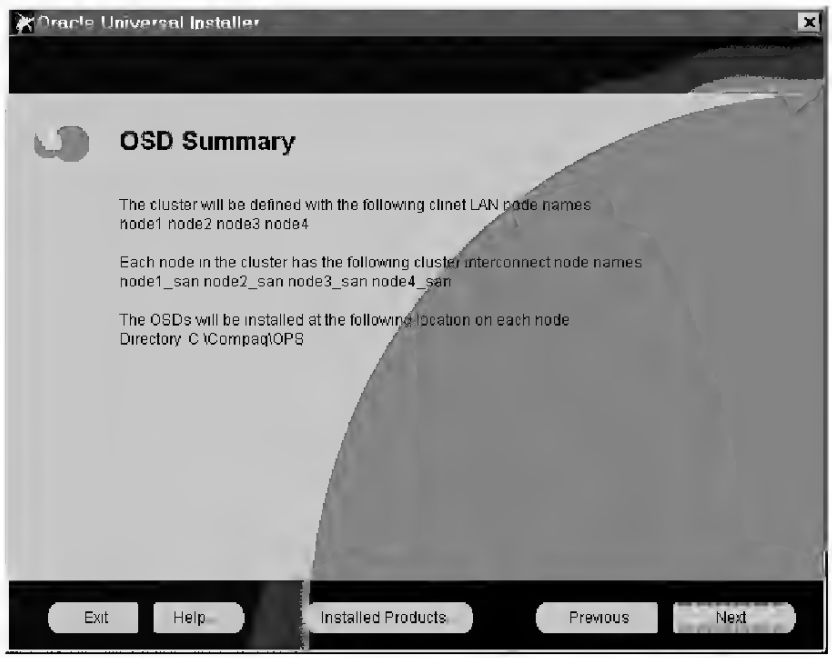
17. Click **Next** to continue. The **OSD Summary** screen appears.


Oracle Universal Installer
OSD Summary
The cluster will be defined with the following clinet LAN node names
node1 node2 node3 node4
Each node in the cluster has the following cluster interconnect node names
node1_san node2_san node3_san node4_san
The OSDs will be installed at the following location on each node
Directory C:\Compaq\OPS
Exit
Help
Installed Products
Previous
Next

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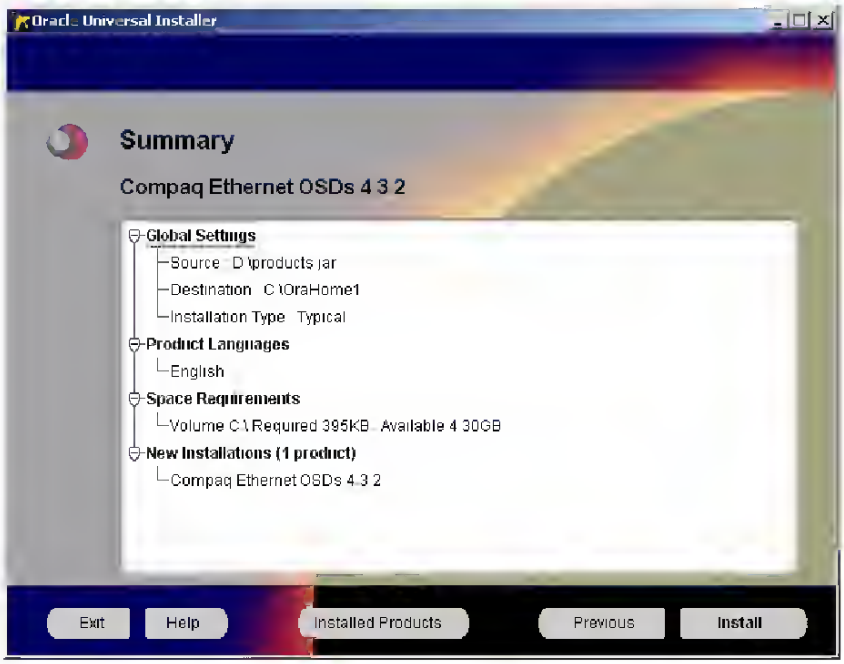
18. If the information on the **OSD Summary** screen is not correct, click **Previous** to modify the previous screens.

    When the information is correct, click **Next** to continue. The **Summary** screen appears.



19. Click **Install** to install the components listed in the summary. At this point, the OUI verifies that the installing node can communicate with other cluster nodes through both the client LAN and cluster interconnect node names. If the OUI cannot communicate with all nodes, this process can take awhile. If the node is not accessible, an error message will appear asking you to check the hostname and the network connection.

20. An **Install** screen appears that shows a percentage completion bar as the installation progresses.

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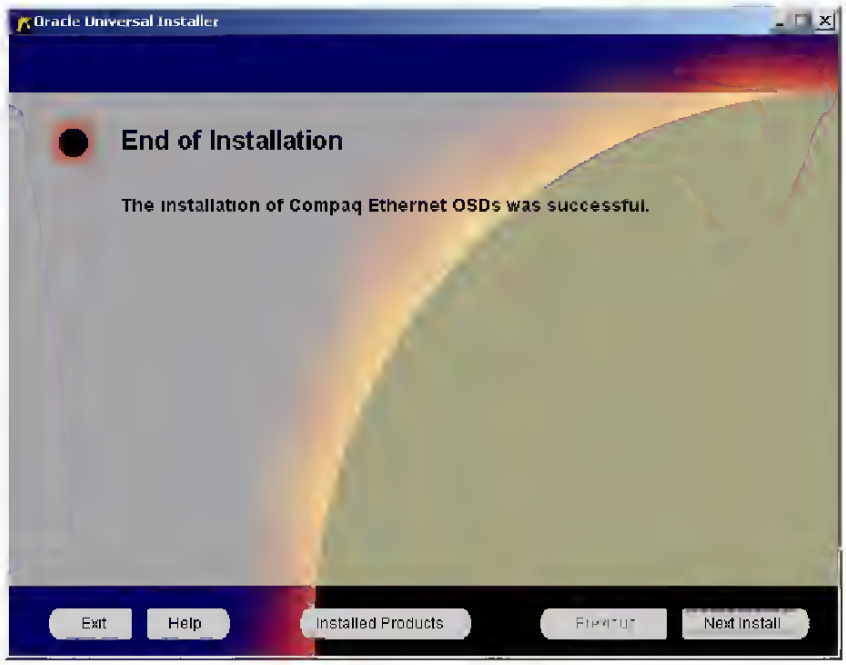
21. When the installation completes, the **End of Installation** screen appears.



22. Click **Exit** to quit the OUI or **Next Install** to install another product.

23. Start the cluster manager, **OracleCMService,** on all nodes in the cluster. This service must be started before installing Oracle software. See the Oracle documentation for information on starting the cluster manager.

Installing Oracle Software

Using the *Oracle8i Parallel Server Setup and Configuration Guide,* follow the steps to install Oracle8*i* Enterprise Edition software on all cluster nodes, including:

- Oracle8*i* Server
- Oracle8*i* Parallel Server Option

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- Oracle8*i* Parallel Server Manager
- Oracle8*i* Enterprise Manager

NOTE: If the Oracle Universal Installer does not offer the option to install Oracle8*i* Parallel Server, it could mean that the OSDs did not install successfully or that the OracleCMService is not running.

After installing Oracle software, the Oracle8*i* documentation instructs you to install vendor-supplied operating system dependent modules (OSDs). You have already completed this step.

Configuring Oracle Software

Configuring Oracle software includes configuring Oracle8*i* Parallel Server, Oracle8*i* Parallel Server Manager, Oracle8*i* Enterprise Manager, and administering multiple instances. Use the *Oracle8i Parallel Server Setup and Configuration Guide* and the *Oracle8i Enterprise Edition for Windows 2000* to configure the Oracle software.

Installing Object Link Manager

IMPORTANT: Before installing and configuring an Oracle database, you must install Object Link Manager on all cluster nodes. Object Link Manager maintains the symbolic links between disk partitions and Oracle data files. Failure to install Object Link Manager can result in the Oracle database not starting or, if it starts, in not finding the correct data.

Windows 2000 Advanced Server assigns disk numbers to drives in the shared storage subsystems based on the order in which the shared storage subsystems are powered on.

The order in which disks are brought online directly affects the disk numbers assigned to the disk, which in turn affects the ability of Oracle8*i* Server to find Oracle data files. If shared storage subsystems are powered off and then powered on in a different order than they were when the cluster was initially configured, the order and numbering of the shared disk drives will change for all nodes in the cluster.

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Object Link Manager simplifies the creation and maintenance of symbolic links between disk partitions and Oracle data files by placing the symbolic link names directly into the disk partitions, thereby tracking the symbolic links dynamically. This means that if the order in which disk drives are brought online changes, Oracle8*i* Server can find the correct data files and can properly start the Oracle database.

You must install Object Link Manager before installing the Oracle database software to ensure that the symbolic links are defined before creating a database.

For instructions on installing and using Object Link Manager, see the readme file on the Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Microsoft Windows 2000 CD at

\Object Link Manager\readme.txt

Additional Notes on Configuring Oracle Software

In addition to the steps outlined in the Oracle documents, you must create a symbolic link for OPS_CMDISK. You should verify access to the shared storage from all nodes of the cluster.

Creating a Symbolic Link for OPS_CMDISK

The OPS_CMDISK data file contains status information for all nodes in the cluster. Using the Object Link Manager GUI, define a partition to be called OPS_CMDISK and commit the change.

Verifying Access to Shared Storage from All Nodes

IMPORTANT: Verify access to shared storage from all nodes in the cluster **before** starting any Oracle instance.

Open Disk Management to verify that the shared disk resources are seen from this node as they are seen from other installed nodes in the cluster.

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Verifying the Hardware and Software Installation

Cluster Communications

Use the ping utility to verify that each node in the cluster can communicate with every other node over the client LAN. Run the ping utility from the installing cluster node. Verify the installing node can communicate with all cluster nodes by pinging the client LAN name. The IP address displayed by the ping utility should be the client LAN IP address.

If you are using an Ethernet cluster interconnect, ping the Ethernet cluster interconnect name. The IP address displayed by the ping utility should be the Ethernet cluster interconnect address. If this is not the case, check the entries in the hosts and lmhosts files at %SystemRoot%\system32\drivers\etc.

Access to Shared Storage from All Nodes

Use Disk Management to verify that the same shared disk resources are seen from this node as they are from other installed nodes in the cluster.

OSDs

After verifying all the nodes have access to the shared storage, start an Oracle instance. For example, at a C: command prompt start an instance by entering:

```
net start oracleservice<SID>
```

If the OSDs are installed correctly, a message will appear indicating that the Oracle service has started successfully.

If the Oracle service did not start successfully, make sure that the OracleCMService is started and the SID is in the Oracle registry. There are two logs that can provide information about why the Oracle service did not start. These logs are:

- \Compaq\OPS\cmsrvr.log
- \Compaq\OPS\nm.log

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Other Verification Tasks

Perform these other verification tasks:

- Verify that Object Link Manager has been installed and is running.
- Verify that the OPS_CMDISK symbolic link has actually been set.

To verify the Object Link Manager has been installed and is running, select the Services icon in the Control Panel. Once there, look for "Oracle Object Service" in the list of services and see if it is shown as "Started".

If the Object Link Manager has been installed and the service is running, verifying that the OPS_CMDISK symbolic link has been set can be done by running the Object Link Manager to see if the link OPS_CMDISK is in the list of links.

Power Distribution and Power Sequencing Guidelines

It is recommended you connect most cluster components to a Compaq power distribution unit (PDU). PDUs connect to an uninterruptible power supply (UPS) or building power. The PDUs and UPSs are the only cluster components connected to a building power source. If there is no UPS, the PDU plugs into building power.

It is also recommended that you connect cluster components, such as servers, storage subsystems, switches, and hubs, to two PDUs and UPSs so the cluster components continue to operate if one PDU or UPS fails.

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Server Power Distribution

Figure 5-9 shows an example of server power distribution for a three-node cluster. Power supply #1 of each server is connected to PDU #1. Power supply #2 of each server is connected to PDU #2.

PDU #1 is connected to UPS #1, and PDU #2 is connected to UPS #2. Each UPS is connected to building power.

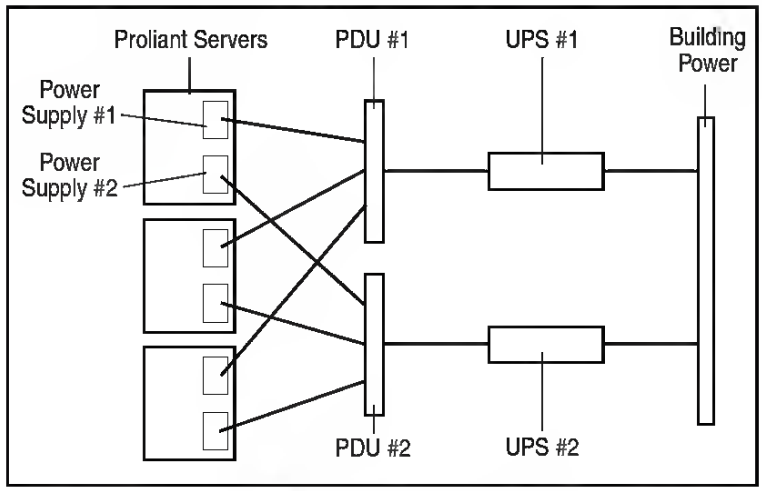

Figure 5-9. Server power distribution in a three-node cluster

Having two PDUs and UPSs in the cluster provides two paths from the servers to building power and means that the cluster stays up and running if a PDU or UPS fails in one of the paths.

RA4000/RA4100 Array Power Distribution

An RA4000/RA4100 Array can have one or two power supplies. If each RA4000/RA4100 Array in the cluster has two power supplies, the power distribution (with respect to connecting them to PDUs and UPSs) can be configured similarly to the example shown for server power distribution. By substituting RA4000/RA4100 Arrays for ProLiant servers in Figure 5-9, you can provide two redundant paths from the RA4000/RA4100 Arrays to building power.

If each RA4000/RA4100 Array has one power supply, connect the RA4000/RA4100 Array to a PDU, connect the PDU to a UPS, and then connect the UPS to building power. If there is no UPS, connect the PDU directly to building power.

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Power Sequencing

Be sure to power up the cluster components in the following order:

1. RA4000/RA4100 Arrays
2. Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches (Power is applied to Storage Hub when the AC power cord is plugged in.)
3. Ethernet hubs or switches
4. ProLiant servers

Be sure to power down the cluster components in the following order:

1. ProLiant servers
2. Ethernet hubs or switches
3. Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches (Power is applied to Storage Hub when the AC power cord is plugged in.)
4. RA4000/RA4100 Arrays

Shutting down and powering off the servers first allows them to perform tasks such as flushing queued database write transactions to disk and properly terminating running processes.

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Chapter 6

Cluster Management

Throughout the life of your cluster, you might need to improve its performance, upgrade hardware components, upgrade software, increase storage capacity, and monitor ongoing activities. This chapter describes these management activities for the Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000). The topics addressed in this chapter include:

- Cluster management concepts
- Management applications
- Software maintenance
- Managing changes to shared storage
- Replacing a cluster node
- Adding a cluster node
- Managing cluster operation

NOTE: The procedures in this chapter contain high-level instructions. The instructions summarize what has either already been discussed in this guide, Oracle documentation, or storage subsystem documentation.

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Cluster Management Concepts

Powering Off a Node Without Interrupting Cluster Services

At some time during the life of your cluster you will need to perform an operation on a cluster node that will require it to be powered off. Physically moving the cluster node, removing a hardware device, and adding a hardware device commonly require the node to be powered off.

It is a good practice to gracefully shut down the node before powering it off. The process of gracefully shutting down a node in a PDC/O2000 can be summarized as:

1. Make sure that clients connecting to the database through the node can reconnect to the database through one of the other nodes.
2. Properly shutdown the Oracle instance running on the node.
3. Shut down the server.

The node can now be powered off safely. The database will remain accessible since the remaining cluster nodes are operating normally.

Managing a Cluster in a Degraded Condition

Due to the high availability benefits of clustering, applications and network clients remain operational even while some cluster components do not. When the cluster enters a degraded condition, it is helpful to follow this troubleshooting process:

1. Determine what caused the degradation.
2. Determine whether the condition affects one cluster node, multiple cluster nodes, or all cluster nodes.

   If one or more nodes is unaffected by the condition, and if enough performance can be obtained from the unaffected nodes, continue operating the database.
3. Determine whether the condition will continue to worsen.

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4. Determine how critical it is to repair the problem.
   - If the problem is not considered to be critical, wait until a non-peak time to service the problem.
   - If the problem is critical but does not affect all cluster nodes, shut down the Oracle instances on the affected nodes and wait until a non-peak time to service the problem.
   - If the problem is critical and affects all the cluster nodes, shut down the database instances on all cluster nodes and correct the problem.

Managing Network Clients Connected to a Cluster

An important aspect of managing network clients is informing users that their applications are now running on a cluster. As the cluster is initially brought into production, it can be helpful to describe in a memorandum the effects a cluster will have on user ability to access the database.

Since users will experience some disruption of service and possibly a performance degradation during a node eviction, they might become concerned about the availability and stability of their applications.

When a node eviction or node integration occurs, the users will notice that for a brief moment they cannot access their database. When users have been properly forewarned of the effects of operating in a clustered environment, they will more readily recognize when such an event is occurring. Most users will then know to wait several seconds before attempting to reaccess their database.

Cluster Events

The majority of cluster events can be viewed either within the System log or within specific error log files. The Oracle8*i* Server events are sent to the Application log and can be viewed from the Event Viewer.

The lower-level software components, such as the cluster manager, send events to error log files.

NOTE: If the OSDs are not installed in the default directory, the log files will be in the same directory as the OSDs.

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The following log files are used:

- The Node Manager (NM), provided by Compaq, logs messages to C:\compaq\ops\nm.log
- By default the OracleCMService sends messages to C:\compaq\ops\cmsrvr.log

Management Applications

Monitoring Server and Network Hardware

Compaq Insight Manager is used to manage the hardware components of your cluster. Compaq Insight Manager, loaded from the Compaq Management CD, is an easy-to-use software utility for collecting server, storage, and network information. Compaq Insight Manager performs the following functions:

- Monitors fault conditions and system status
- Monitors shared storage and interconnect adapters
- Forwards server alert fault conditions
- Remotely controls servers

In Compaq servers, each hardware subsystem, such as network adapters, system processors, and system memory, has a robust set of management capabilities. Compaq Full Spectrum Fault Management notifies of impending fault conditions.

Several steps are required to configure the system for Insight Manager. For example, you must:

- Load Insight agents on each cluster node.
- Install the Compaq Insight Manager Console.
- Make sure that proper user rights are granted.

For additional information concerning Compaq Insight Manager, see the Compaq Server Setup and Management pack.

Compaq Insight Manager XE is a web-based management system that can also be used to monitor cluster hardware components. Compaq Insight Manager XE is an optional CD available upon request from the Compaq System Management website at

www.compaq.com/sysmanage

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Managing Shared Drives

There are two levels of management with shared drives in RA4000 Arrays or RA4100 Arrays. The physical disks and the drive arrays created from them are managed with the Array Configuration Utility (ACU). The logical drives are created and managed with the Disk Management utility.

The ACU is first run during initial configuration of the shared storage subsystem and can be run any time afterward to view existing drive arrays, modify existing drive arrays, or add new drive arrays. The ACU is available on the SmartStart and Support Software CD, which is found in the Compaq Server Setup and Management pack. For additional information about the ACU, see the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.

Disk Management is first run after the drive arrays have been created by the ACU. Disk Management is used to partition the drive arrays, create logical drives, and assign volume labels. For additional information about Disk Management, see your Microsoft Windows 2000 Advanced Server documentation.

Monitoring Redundant Fibre Channel Fabrics

Each redundant Fibre Channel Fabric in a PDC/O2000 contains this hardware:

- One or more Compaq StorageWorks RAID Array 4100s (RA4100 Arrays) or Compaq StorageWorks RAID Array 4000s (RA4000 Arrays)
- Two Compaq StorageWorks RAID Array 4000 Controllers (RA4000 Array Controllers) installed in each RA4000 Array or RA4100 Array
- At least two Compaq StorageWorks Fibre Channel SAN Switches (Fibre Channel SAN Switches)
- At least two Compaq StorageWorks 64-bit/66-MHz Fibre Channel Host Adapters or Compaq StorageWorks Fibre Channel Host Adapter/Ps (Fibre Host Adapters) installed in each server
- Gigabit Interface Converter-Shortwave (GBIC-SW) modules
- Fibre Channel cables

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Compaq Secure Path software can detect failures in redundant Fibre Channel Fabric components. When a failure occurs on an active path, Secure Path reroutes I/O through the standby path, allowing applications to continue processing.

The Secure Path product CD is included in the cluster kit for the Compaq Parallel Database Model PDC/O2000 for Oracle8*i* on Microsoft Windows 2000.

Monitoring Redundant Fibre Channel Arbitrated Loops

Each redundant FC-AL in a PDC/O2000 contains this hardware:

- One or more RA4100 Arrays or RA4000 Arrays
- Two RA4000 Array Controllers installed in each RA4000 Array or RA4100 Array
- At least two Compaq StorageWorks Storage Hubs (Storage Hubs) or Compaq StorageWorks FC-AL Switches (FC-AL Switches)
- At least two Fibre Host Adapters installed in eacb server
- GBIC-SW modules
- Fibre Channel cables

The Fibre Channel Fault Isolation Utility (FFIU) can verify the integrity of a newly installed or existing FC-AL installation. This utility provides fault detection and help in locating a failing device on an FC-AL. FFIU is on the SmartStart and Support Software CD.

Compaq Secure Path software can detect failures in redundant Fibre Channel Fabric components. When a failure occurs on an active path, Secure Path reroutes I/O through the standby path, allowing applications to continue processing.

The Secure Path product CD is included in the cluster kit for the Compaq Parallel Database Model PDC/O2000 for Oracle8*i* on Microsoft Windows 2000.

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Monitoring the Database

Oracle8*i* Enterprise Manager uses agents to continuously monitor database activities and offer a graphical console allowing administrators to manage the database. From the Enterprise Manager Console, the administrator can administer, diagnose, and tune multiple databases. Jobs can also be scheduled, software can be distributed, and objects and events can be monitored from the console.

Several steps are required to properly configure the system for Oracle8*i* Enterprise Manager. Additional steps are required to integrate the management of parallel databases. For example, you must do the following:

- Create an Enterprise Manager Repository on the console node.
- Obtain sufficient rights on the console machine as well as on the managed cluster nodes.
- Install Oracle agents on each managed node.

Be sure to read through the Oracle documentation. For Oracle8*i* Enterprise Manager, see:

- *Oracle Enterprise Manager Administrator's Guide*
- *Oracle Enterprise Manager Configuration Guide*
- *Oracle Enterprise Manager Concepts Guide*
- *Oracle8i Parallel Server Setup and Configuration Guide*
- *Oracle8i Parallel Server Concepts*
- *Oracle8i Parallel Server Administration, Deployment, and Performance*

Oracle8*i* Enterprise Manager and its corresponding documentation are shipped as part of Oracle8*i* Enterprise Edition.

Remotely Managing a Cluster

Oracle8*i* Enterprise Manager, Compaq Insight Manager, and Compaq Insight Manager XE can be run from any network client machine that has network access to the cluster nodes. They can operate on Windows NT Server, Windows 95, or Windows 2000.

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Before installing Compaq Insight Manager, Compaq Insight Manager XE, or Oracle8*i* Enterprise Manager, it is recommended that you read through the corresponding documentation to determine how to set up and configure each of these programs to run remotely.

Software Maintenance for Oracle8*i*

Deinstalling the OSDs

At some point, you might want to deinstall the operating system dependent modules (OSDs). Some example situations are:

- When a node is being permanently removed from the cluster
- When a node is being replaced
- When a node is being added to the cluster
- When the OSDs are being upgraded to a newer revision level

Use Oracle Universal Installer to deinstall the OSDs.

IMPORTANT: The Oracle Universal Installer removes the OSDs from all cluster nodes. To properly maintain the cluster, the Oracle Universal Installer cannot remove the OSDs from individual nodes. After the OSDs are deinstalled, the cluster is disbanded and cannot run until the OSDs are reinstalled on all the nodes.

Be sure to shut down the Oracle instance on all nodes and stop the Oracle services running on all nodes prior to removing the OSDs.

To deinstall the OSDs:

1. Log in as a user who has administrator privileges on all nodes in the cluster.
2. Insert the Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Microsoft Windows 2000 CD into the CD-ROM drive of the primary node. This is the node where the OSDs were installed originally.

   IMPORTANT: To deinstall the OSDs, you must run the Oracle Universal Installer from the same node where the OSDs were installed.

3. If autorun is enabled, the Oracle Universal Installer **Welcome** screen appears.

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4. If autorun is disabled, enter *d:\setup* at a C: prompt. Substitute the letter assigned to the CD-ROM drive for *d*. The Oracle Universal Installer **Welcome** screen appears.

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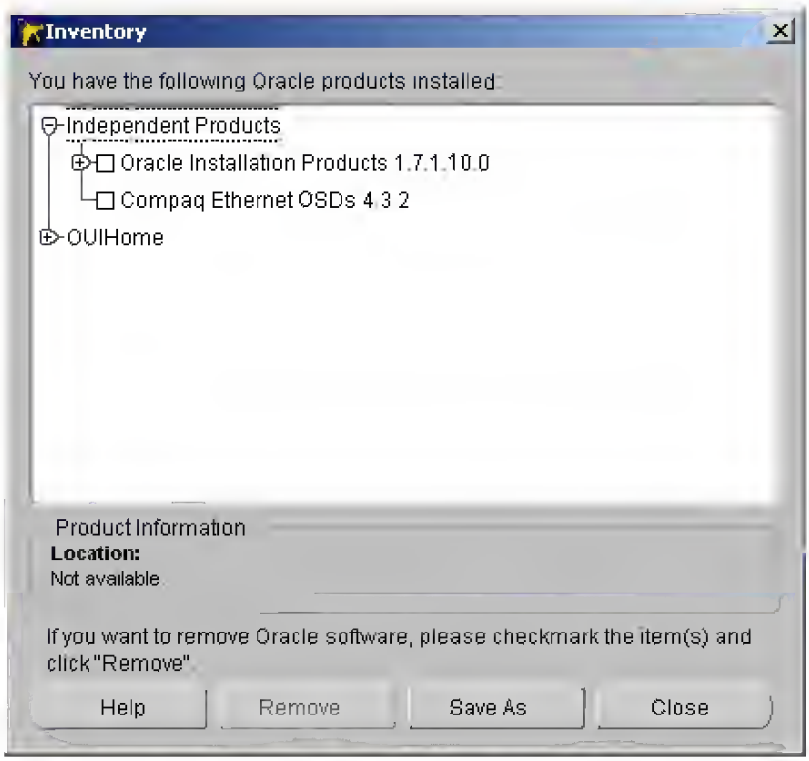
5. Click **Deinstall Products.** Next, a window containing an inventory of the installed components appears. The following shows the **Inventory** screen that is displayed when Ethernet is used for the cluster interconnect.



6. Select **Compaq Ethernet OSDs** and click **Remove.**

NOTE: Your screen might display later revision levels for the OSDs.

7. Follow the Oracle Universal Installer directions to complete the deinstallation.

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Upgrading Oracle8*i* Server

The design of the PDC/O2000 is tightly integrated with Oracle8*i* Server. Significant changes in Oracle8*i* Server will likely affect the operation of the cluster.

Before upgrading to any new release of Oracle8*i* Server, consult your Compaq and Oracle service representatives. Make sure that the new release is certified and supported on the PDC/O2000, and get assistance to determine which procedure you should follow to perform the upgrade properly.

Upgrading the OSDs

During the life of your PDC/O2000, you will need to upgrade the operating system dependent modules as new versions are released.

Before beginning the upgrade procedure:

1. Make sure that the person performing the upgrade has administrative privilege on each cluster node.
2. Make sure that all cluster nodes are active. From each node, run the ping utility to verify that every node recognizes the other nodes by host name.
3. Shut down the Oracle database on all nodes.
4. Stop the Oracle services (OracleCMService, OracleNMService, and OracleService*SID*) on all nodes.

Once you have completed these steps, you can deinstall the existing OSDs and install the new versions as described in the following procedure.

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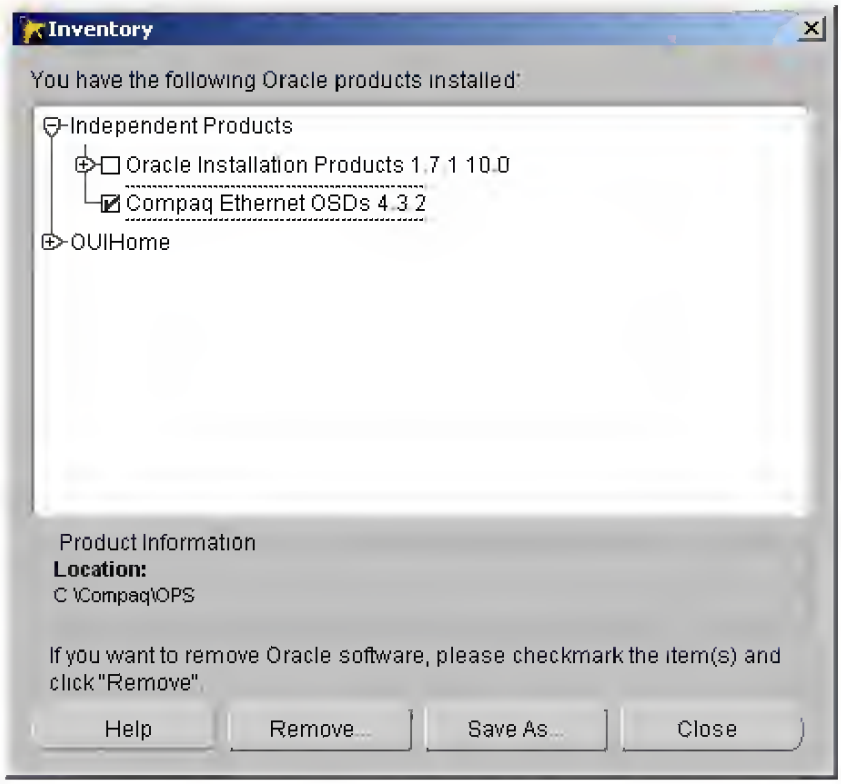
Upgrading the Ethernet OSDs

To upgrade the Ethernet OSDs:

1. Insert the CD containing the new revision of the OSDs into the CD-ROM drive on the primary node. (This is the node that was used for the previous installation of the OSDs.)

   The **Oracle Universal Installer** window is displayed.

2. Click **Deinstall Products**. The **Inventory** screen displays a list of installed components.



3. Select **Compaq Ethernet OSDs** and click **Remove**.

   The Oracle Universal Installer removes all Ethernet OSDs.

4. After the deinstallation has finished, restart all nodes.

5. Install the new Ethernet OSDs from the new by following the procedure described under "Installing Compaq OSDs" in Chapter 5, "Installation and Configuration."

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6. After installing the new Ethernet OSDs, restart OracleCMService and OracleNMService on all nodes.
7. Restart the Oracle instances on all nodes.

Deinstalling a Partial OSD Installation

While not a common occurrence, the Oracle Universal Installer might not be able to complete the installation of the Compaq Ethernet OSDs. An incomplete OSD installation could result for various reasons, for example:

- A client LAN cable is no longer seated tightly into its connector.
- The node from which you are running the OUI cannot communicate with all other nodes in the cluster.
- The user running the OUI does not have administrator privileges on all cluster nodes.

An incomplete installation can result in a partial installation of the OSDs on the cluster. If this occurs, you must clean up after the partial installation (by removing it) before you can successfully run the Oracle Universal Installer again.

To remove a partial OSD installation:

1. Insert the Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Microsoft Windows 2000 CD into the CD-ROM drive of a cluster node.
2. From a command prompt, navigate to the CD-ROM drive.
3. Connect to the **\Utilities** directory.
4. Run the uninstall utility by entering:

   ```
   uninstallOSD
   ```

5. Restart the node.
6. Repeat steps 1 through 5 on all other nodes in the PDC/O2000 cluster.

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Upgrading Oracle8*i* Server

The design of the PDC/O2000 is tightly integrated with Oracle8*i* Server. Significant changes in Oracle8*i* Server will likely affect the operation of the cluster.

Before upgrading to any new release of Oracle8*i* Server, consult your Compaq and Oracle service representatives. Make sure that the new release is certified and supported on the PDC/O2000, and get assistance to determine which procedure you should follow to perform the upgrade properly.

Managing Changes to Shared Storage Components

Replacing a Failed Disk

At some point, you might need to replace a failed drive in an RA4000 Array or RA4100 Array. It is assumed you are employing RAID levels 0, 1, 0+1, 4, or 5 for all devices in the storage array.

IMPORTANT: If the failed drive is not part of a fault-tolerant drive array you can lose some or all of the data on the failed drive.

With RAID employed, the effects of replacing a drive are felt only by the storage subsystem. The operating system and Oracle are unaware of the activity.

The removal of a drive in an RA4000 Array or RA4100 Array must follow certain rules are that interpreted by reading the LEDs on the disk drive. Before proceeding, locate the information in the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide* that describes the conditions under which a drive can be removed. Once you have determined it is safe to remove the drive, open both latches on the drive tray and remove the drive from the drive bay. Put the replacement drive into the drive bay and snap the latches in place.

CAUTION: Failure to follow the rules described in the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide* can result in loss of data.

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Adding Disk Drives to Increase Storage Capacity

During the life of your PDC/O2000 cluster, you might need to expand the capacity of an RA4000 Array or RA4100 Array. The following steps describe how to add drives to an RA4000/RA4100 Array and how to allocate the added disk capacity to Oracle.

The drive can be added and allocated to Windows 2000 Advanced Server while the database is online. The following summarizes the procedure.

1. Physically add the drives to the RA4000/RA4100 Array.
2. On the primary node, run the Array Configuration Utility to create drive arrays, configured with RAID, and then create logical drives.
3. Using Disk Management, create an extended partition on each of the logical drives.
4. Using Disk Management, create logical partitions within each extended partition.

IMPORTANT: Do not format the drives. Oracle Parallel Server uses raw partitions, which requires that the drive not be formatted with any file system.

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5. Verify that the same shared disk resources are seen from every node in the cluster by running Disk Management on eacb node.
6. Make sure you can see the same shared disk resources from each node using Secure Path Manager as you can using the Disk Management.
7. Perform the necessary Oracle commands to associate the new data files to the database.

Refer to the *Oracle8i Parallel Server Setup and Configuration Guide* for more detailed instructions.

Adding an RA4000/RA4100 Array

You must shut down the cluster to add an RA4000/RA4100 Array. The following steps summarize the procedure:

1. Shut down the Oracle instance on each cluster node.
2. Stop the Oracle services running on each node.
3. Shut down Windows 2000 Advanced Server on each node and power off all the cluster nodes.
4. Power off all of the RA4000/RA4100 Arrays.

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5. Insert drives into the added RA4000/RA4100 Array.
6. Using the Fibre Channel cables, physically connect the RA4000 Array Controllers in the added RA4000/RA4100 Array to the Fibre Channel SAN Switches, FC-AL Switches, or Storage Hubs.
7. Connect all of the RA4000/RA4100 Arrays to a power source and restart them.
8. Restart the primary cluster node.
9. On the primary node, run the Array Configuration Utility to create drive arrays, configured with RAID, and then create logical drives.
10. Using Disk Management, create an extended partition on each of the logical drives.
11. Using Disk Management, create logical partitions within each extended partition.

IMPORTANT: Do not format the drives. Oracle8*i* Parallel Server uses raw partitions, which requires that the drive not be formatted with any file system.

12. Power on the other cluster nodes.
13. Verify that the same shared disk resources are seen from every node in the cluster by running Disk Management on each node.
14. Make sure you can see the same shared disk resources from each node using Secure Path Manager as you can using the Disk Management.
15. Define the active array controller in the newly-added RA4000/RA4100 Array.
16. Perform the necessary Oracle commands to associate the new data files to the database.

Refer to the *Oracle8i Parallel Server Setup and Configuration Guide* for more detailed instructions.

Replacing a Failed Fibre Host Adapter

To replace a failed Fibre Host Adapter in a cluster node:

1. Shut down the Oracle instance on the node.
2. Shut down the Oracle services running on the node.
3. Shut down the server.
4. Power off the node.

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5. From the Fibre Host Adapter, disconnect the Fibre Channel cable installed between the Fibre Host Adapter and its Fibre Channel SAN Switch, FC-AL Switch, or Storage Hub.
6. Remove the failed Fibre Host Adapter and insert a new one.
7. From the new Fibre Host Adapter, connect the Fibre Channel cable that runs to its Fibre Channel SAN Switch, FC-AL Switch, or Storage Hub.
8. Power on the node.
9. Restart the Oracle services on the node.
10. Start up the Oracle instance on the node.

Replacing a Cluster Node

Before replacing a node, verify that the new configuration is supported by the PDC/O2000. To determine if your new server is supported, see the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* at

www.compaq.com/solutions/enterprise/ha-pdc.html

IMPORTANT: With some possible exceptions, the servers in the cluster must be set up identically. For example, this means using one model server for all nodes. The cluster components common to all nodes in the cluster must be identical; for example, the cluster interconnect adapters, amount of memory, cache, and number of CPUs must be the same in each cluster node.

Replacing a node consists of removing it logically from the cluster, removing it physically from the cluster, then adding a new server to take its place.

Removing the Node

1. Record pertinent information that will be needed when configuring the replacement node. Such information includes:
   - The IP address and network name of the client LAN adapters
   - For an Ethernet cluster interconnect, the IP address and network name of the Ethernet cluster interconnect adapters
2. If the new node will use applications or data that is stored locally on the node being replaced, back up that data to a removable storage medium or to a remote file server that can be restored onto the replacement node.
3. Stop the Oracle instance on the node to be removed.

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4. Stop all Oracle services on the node to be removed.
5. Shut down the server on that node and power it off.
6. Disconnect the Fibre Channel cables between the evicted node and the Fibre Channel SAN Switches, FC-AL Switches, or Storage Hubs.
7. Disconnect the cluster interconnect cables from the evicted node and label them as the cluster interconnect cables.
8. Disconnect the client LAN cables from the evicted node and label them as the client LAN cables.
9. If adapters from the evicted node will be used in the new node, move the adapters to the new node.

Adding the Replacement Node

Adding the replacement node involves the following activities:

- Preparing the replacement node
- Installing the cluster software

NOTE: These subsections contain a high-level outline of the steps to follow. If you need detailed instructions, read Chapter 5, "Installation and Configuration."

Preparing the Replacement Node

Several steps should be performed on the replacement node before it is integrated into the cluster.

Prior to integrating the node into the cluster, perform the following steps:

1. Connect the server for the replacement node to the cluster interconnect components and the client LAN. Power on the replacement node. Although physically connected to the cluster, the node is not yet integrated into the cluster.
2. Start the replacement node with the Compaq SmartStart and Support Software CD in the CD-ROM drive.
3. Use the Compaq System Configuration Utility to configure the hardware settings of the node and its adapters.
4. Use the Compaq Array Configuration Utility to configure the server's local non-shared disks with RAID.

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5. Install and configure Windows 2000 Advanced Server with Service Pack 1 or later (whichever is installed on the other cluster nodes).
6. Install necessary Compaq drivers and utilities from the Compaq SmartStart and Support Software CD.
7. Install Fibre Host Adapters in the replacement node in the same slot locations used in the other cluster nodes.
8. Enter unique IP addresses and node names for each node in the hosts and lmhosts files located at %SystemRoot%\system32\drivers\etc.
9. Install Secure Path for Windows 2000. See "Installing Secure Path Software for Windows 2000" in Chapter 5, "Installation and Configuration."
10. Using Fibre Channel cables, connect the Fibre Host Adapters in the replacement node to the Fibre Channel SAN Switches, FC-AL Switches, or Storage Hubs.
11. Restart the replacement node.
12. Verify TCP/IP connectivity between the replacement node and the existing cluster nodes. Run the ping utility from the replacement node, pinging the client LAN adapters on all other nodes. If Ethernet is used as the cluster interconnect, also ping the cluster interconnect adapters of all other nodes.
13. Verify the replacement node can access the shared storage. From the replacement node, start Disk Management to verify that the same shared disk resources are seen from this node as they are seen from other installed nodes in the cluster. Also make sure you can see the same shared disk resources from the replacement node using Secure Path Manager as you can using Disk Management.

Installing the Cluster Software

Now that the replacement node is configured and physically connected to the cluster, the next procedure is to integrate the node into the cluster. This involves installing the low-level cluster management software and the OSDs. It also involves installing the application-level cluster software, including Oracle8*i* Server with the Oracle8*i* Parallel Server Option.

All activities in this procedure are facilitated with the Oracle Universal Installer (OUI). The installation is further simplified in that almost all steps are performed from a single server, the primary cluster node.

To install the cluster software, perform the following steps:

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1. To add a node to the cluster, you must disassemble the existing cluster and then reform it to include the replacement node. Do the following on all original cluster nodes (not the replacement node):
   a. Shut down the Oracle instance.
   b. Stop all Oracle services.
   c. Deinstall the OSDs using the OUI from the original installing node.
   d. Restart all nodes to complete the deinstallation process.
2. If the replacement node is the node on which you originally installed the OSDs, do the following on all nodes:
   a. Shut down the Oracle instance.
   b. Stop all Oracle services.
   c. Uninstall the OSDs from each node by running uninstall OSD, located in the Utilities directory of the installation CD.
   d. Restart all nodes to complete the deinstallation process.
3. Use the OUI to reinstall the OSDs on each cluster node, including the original nodes and the replacement node.
4. Restart each cluster node to complete the OSD installation process.
5. Verify that Object Link Manager has been installed on the replacement node. See "Installing the Object Link Manager" in Chapter 5, "Installation and Configuration."
6. Install Oracle8*i* Server with the Oracle8*i* Parallel Server Option on the replacement node.
7. Restart the replacement node which, upon restart, is now fully integrated into the cluster.
8. At this point, all further operations are specific to Oracle configuration. Refer to the Oracle setup and configuration documentation for information on configuring Oracle software.

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Adding a Cluster Node

Before adding a node, verify the new configuration is supported by the PDC/O2000. To determine if your new server is supported, see the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* at

www.compaq.com/solutions/enterprise/ha-pdc.html

IMPORTANT: With some possible exceptions, the servers in the cluster must be set up identically. For example, this means using one model server for all nodes. The cluster components common to all nodes in the cluster must be identical, for example, the cluster interconnect adapters, amount of memory, cache, and number of CPUs must be the same in each cluster node.

During the life of the PDC/O2000, you might need to add a new node to the cluster. A desire to increase performance or throughput can drive this decision. Adding another node also can increase overall availability of the system.

This can be a time-consuming and complex procedure. Be sure to read through all of the following directions as well as those in the Oracle documentation before starting.

Adding a new node involves the following activities:

- Preparing the new node
- Preparing the existing cluster nodes
- Installing the cluster software

These subsections contain a high-level outline of the steps to follow. If you need detailed instructions, read through Chapter 5, "Installation and Configuration."

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Preparing the New Node

To minimize downtime of the cluster, several preparation steps should be performed on the new node before it is integrated into the cluster.

Prior to integrating the new node into the cluster, perform the following steps:

1. Connect the server for the new node to the cluster interconnect components and to the client LAN. Power on the new node. Although physically connected to the cluster, the node is not yet integrated into the cluster.
2. Start the new node with the Compaq SmartStart and Support Software CD in the CD-ROM drive.
3. Use the Compaq System Configuration Utility to configure the hardware settings of the node and its adapters.
4. Use the Compaq Array Configuration Utility to configure the node's local non-shared disks with RAID.
5. Install and configure Windows 2000 Advanced Server with Service Pack 1 or later (whichever is installed on the other cluster nodes).
6. Install all necessary Compaq drivers and utilities from the Compaq SmartStart and Support Software CD, including the drivers for the Fibre Host Adapters.
7. Enter unique IP addresses and node names for each node in the hosts and lmhosts files located at %SystemRoot%\system32\drivers\etc.
8. Install Secure Path for Windows 2000 on the new node. See "Installing Secure Path Software for Windows 2000" in Chapter 5, "Installation and Configuration."
9. Using Fibre Channel cables, connect the Fibre Host Adapters in the new node to the Fibre Channel SAN Switches, FC-AL Switches, or Storage Hubs.

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10. Restart the new node.
11. Verify TCP/IP connectivity between the replacement node and the existing cluster nodes. Run the ping utility from the replacement node, pinging the client LAN adapters on all other nodes. If Ethernet is used as the cluster interconnect, also ping the cluster interconnect adapters of all other nodes.
12. Verify that the new node can access the shared storage. From the replacement node, use Disk Management to verify that the same shared disk resources are seen from this node as they are seen from other installed nodes in the cluster. Also make sure you can see the same shared disk resources from the replacement node using Secure Path Manager as you can using Disk Management.

Preparing the Existing Cluster Nodes

To prepare the existing cluster nodes for adding a new node:

1. Add the unique IP addresses and node names for the new node in the hosts and lmhosts files of each existing cluster node. These files are located at %SystemRoot%\system32\drivers\etc.
2. Verify TCP/IP connectivity between the new node and the existing cluster nodes. Run the ping utility from the new node, pinging the client LAN adapters on all other nodes. If Ethernet is used as the cluster interconnect, ping the cluster interconnect adapters of all other nodes.

Installing the Cluster Software for Oracle8*i*

Now that the new node is configured and physically connected to the cluster, the next procedure is to integrate the node into the cluster. This involves installing the low-level cluster management software and the OSDs. It also involves installing the application-level cluster software, including Oracle8*i* Server with the Oracle8*i* Parallel Server Option.

The cluster must be brought offline to install the cluster software. Because the database will be unavailable while configuring the Oracle software, it is recommended that this procedure be performed during non-peak work hours.

NOTE: As a precaution, it is recommended that you back up the database.

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To install the cluster software, perform the following steps:

1. To add a node to the cluster, you must disassemble the existing cluster and then reform it to include the new node. Do the following on all original cluster nodes (not the new node):
   a. Shut down the Oracle instance.
   b. Stop all Oracle services.
   c. Deinstall the OSDs by running the OUI on the node on which the OUI was originally run.
   d. Restart all nodes to complete the deinstallation process.
2. Reinstall the OSDs using the OUI on the installing node.

   NOTE: When prompted for the names of the nodes, specify the original nodes and the new node.

3. Verify that Object Link Manager is installed on the new node. See "Installing Object Link Manager" in Chapter 5, "Installation and Configuration."
4. Restart original nodes to complete the OSD installation process.
5. Start the OracleCMService on each cluster node.
6. Install Oracle8*i* Server with the Oracle8*i* Parallel Server Option by using the OUI on the new node. Select only the new node name when asked which node to install the software on. See the *Oracle8i Parallel Server Setup and Configuration Guide* for details on installing and configuring the Oracle software.
7. Once the configuration of the Oracle software is complete, start the Oracle services and Oracle instances on each cluster node.

   NOTE: The addition of an Oracle instance that runs on the new node requires the creation of two additional database log files and additional rollback segments to the database.

   After the new partitions are created for the log files and rollback segments, use the Object Link Manager GUI to set the symbolic link to the log files and rollback segments.

   NOTE: It is recommended that each node in the cluster be rebooted to ensure that new partitions on the shared storage can be seen by all nodes.

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Monitoring Cluster Operation

Tools Overview

Several tools exist to monitor the operation of your cluster. Use the tools to regularly monitor the operation of each node and each Oracle instance. The gathered information might identify a disparity in the workload being performed by each node, which signifies a need to adjust the distribution of the workload so that the overall cluster performance is maximized.

- Compaq Insight Manager and Compaq Insight Manager XE can be used to gather low-level, in-depth hardware statistics for the server and networking hardware components used in the cluster.
- Windows 2000 Performance Monitor gathers performance characteristics of many *objects*. Examples of monitored *objects* are memory, processor, hard drive performance, network software, and application software.
- Oracle8*i* Performance Manager captures, computes, and presents performance data about the Oracle database. Specific data about Oracle8*i* Parallel Server metrics are monitored and viewed with this application.
- Secure Path Manager monitors the hardware components on the redundant Fibre Channel Fabric or redundant FC-AL paths. If a failure occurs along an active I/O path, Secure Path reroutes I/O through the defined standby path.

Using Secure Path Manager

Secure Patb is a high availability software product that provides continuous data access for RA4000/RA4100 Arrays. Redundant hardware, advanced RAID technology, and automated failover capability are used to enhance fault tolerance and availability. Secure Path, in conjunction with the redundant Fibre Channel Fabric or redundant FC-AL topologies used in your PDC/O2000, effectively eliminates single points of failure in the storage system, disk drives, the array controllers, switching devices, cluster interconnect hardware, and Fibre Host Adapters.

NOTE: This section assumes that storagesets have already been configured using the Array Configuration Utility and that the drives have been partitioned with Disk Management.

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Secure Path Manager is the cluster management component of Secure Path. Secure Path Manager provides a Graphical User Interface (GUI) utility that:

- Reports the status of the I/O paths in each redundant FC-AL or redundant Fibre Channel Fabric.
- Reports disk status (path assignment, failover, and failback activity).
- Enables automatic drive failback upon path restoration.

It is recommended that Secure Path Manager GUI remain active (or minimized) to provide continuous Secure Path status monitoring.

IMPORTANT: If you make changes to the Secure Path Agent Configuration, the changes will not go into effect until you stop and restart the Secure Path Agent Service. From **Administrative Tools**, open the **Services** screen, select "**Secure Path Agent**," and restart it by right-clicking on it or selecting **Restart** from the tool bar.

Monitoring Storage Systems

The Storage System View of Secure Path Manager displays each RA4000/RA4100 Array, configured array controllers, and associated storagesets. When you highlight a storageset in Storage System View, Secure Path Manager displays information about the physical I/O paths from each node to that storageset. The following information is displayed for each path:

- The Secure Path host system (node) that has an established access path to the storageset.
- The array controller servicing the path.
- The physical port number of the Fibre Host Adapters servicing the path. This is a relative number determined by Windows 2000's order of discovery for Fibre Host Adapters on that node.
- The physical Bus, Target, and logical drive numbers describing the path address for the storageset.
- A user-selectable Path Mode parameter that specifies path behavior during nominal and failure conditions. Path Mode may be set to Preferred, Alternate, Pre-Offline (Preferred and Offline), or Alt-Offline (Alternate and Offline).
- A set of State attributes that describe the current operational condition of the path. Paths may exist in Active, Failed, or Available states.

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Manipulating Storagesets and I/O Paths

You can use Secure Path Manager to perform the following actions on the storagesets and I/O paths that are managed by Secure Path Manager:

- Move a storageset from one array controller to another. Use this action when you want to change the ownership of a storageset from one array controller to the other.
- Make an I/O path Alternate. Use this action when you have Load Distribution enabled and you want to disable I/O operations to one or more I/O paths.
- Make an I/O path Preferred. Use this action when you have Load Distribution enabled and you want to re-enable I/O operations to a path that you have previously disabled.
- Change the Preferred I/O path. Use this action when Load Distribution is disabled, there are multiple I/O paths available to a storageset on the same controller and you wish to select a new Preferred Path for normal I/O operations.
- Make an I/O path Offline. Use this action when you want to prevent that path from being used for any I/O operations under any circumstances.
- Make an I/O path Online. Use this action when you want to return a path that is currently in the "Alt-Offline" or "Pre-Offline" mode to its original mode.
- Verify an I/O path. Use this action when you want Secure Path Manager to determine the current state of a path.
- Repair an I/O path. Use this action when you want Secure Path Manager to restore access to a failed path after the problem has been corrected.

Refer to the Compaq documentation provided with the Secure Path software for details on performing these operations.

Detecting I/O Path and Array Controller Failures

Secure Path Manager periodically monitors the status of all systems in your storage profile at a rate determined by the Polling Interval storage profile parameter. To indicate failures, icons are used and path states are set to FAILED in the Secure Path Manager GUI. In addition, failover events are logged by the RaiDisk driver in the Event Viewer.

You should routinely monitor Secure Path Manager status to check for the occurrence of failover events that might compromise either the performance or availability of storage resources.

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Note that Secure Path Manager client is not required to be running in order for Secure Path to protect path availability. The RaiDisk device driver running on cluster nodes handles Secure Path's protection capability.

Refer to the Secure Path documentation for descriptions of the icons used to indicate changes in path and controller status.

Identifying I/O Path and Array Controller Failures

The icons and other information in the Secure Path Manager views can help you identify the source of I/O path and array controller failures. See the Secure Path documentation for detailed descriptions of the procedures for performing these activities.

Uninstalling Secure Path

To remove Secure Path software from your cluster, perform these steps from each cluster node:

1. Open the Control Panel and choose **Add/Remove Programs.**
2. Select **SecurepathClient for Windows 2000 on RAID Array 4000/4100 v3.1** and click **Change/Remove.**
3. Click **OK** in the resulting window.
4. Select **Securepath Server for Windows 2000 on RAID Array 4000/4100 v 3.1** and click **Change/Remove.**

   NOTE: The version numbers displayed here are subject to change.
5. Click **OK** in the resulting window.
6. Click **YES** to stop the Secure Path Agent so that the uninstall can proceed properly.
7. Restart the node.
8. Repeat steps 1 through 7 for all other nodes in the cluster.

   NOTE: To aid in the reinstallation of Secure Path, the file "client.ini" is not removed.

The uninstallation process is complete.

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Chapter 7

Troubleshooting

This chapter addresses potential problems you might encounter as you install, configure, test, and operate your Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000). This chapter is organized as follows:

- Basic troubleshooting tips
- Troubleshooting Oracle8*i* and operating system dependent module (OSD) installation problems and error messages
- Troubleshooting node-to-node connectivity problems
- Troubleshooting client-to-cluster connectivity problems
- Troubleshooting shared storage problems
- Troubleshooting Secure Path

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Basic Troubleshooting Tips

Power

Verify that the following are all powered on:

- Cluster nodes
- StorageWorks RAID Array 4000s (RA4000 Arrays) or StorageWorks RAID Array 4100s (RA4100 Arrays)
- Compaq StorageWorks Fibre Channel SAN Switches (Fibre Channel SAN Switches), Compaq StorageWorks Storage Hubs (Storage Hubs), or Compaq StorageWorks FC-AL Switches (FC-AL Switches)
- Switches or hubs for the cluster interconnect

The correct power-on sequence is:

- RA4000 Arrays or RA4100 Arrays
- Fibre Channel SAN Switches, FC-AL Switches, or Storage Hubs (Storage Hub power is applied when the AC cord is plugged in.)
- Ethernet switches/hubs
- ProLiant servers

NOTE: The Storage Hub and some network hub or switch devices do not have on/off buttons; they receive power when the power cord is plugged in.

Physical Connections

Verify that all cable connections between the following components are properly made. Where redundant connections exist, be sure that the redundant paths are cabled correctly between:

- Cluster nodes and the cluster interconnect switches or hubs
- Cluster nodes and the client LAN switches or hubs
- Fibre Host Adapters in the cluster nodes and the Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches
- Storage Hubs, FC-AL Switches, or Fibre Channel SAN Switches and the Compaq StorageWorks RAID Array 4000 Controllers (RA4000 Array Controllers) installed in each RA4000/RA4100 Array

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Access to Cluster Components

Once the physical connections have been checked, ensure that communication is occurring between all the cluster components.

- To test the redundant Ethernet cluster interconnect and client LAN connections, use the ping utility. From each cluster node, ping the Ethernet cluster interconnect adapter or port located in the other nodes. Similarly, from each cluster node, ping the name, then the address, of the client LAN Ethernet adapter or port located in the other nodes. A correct ping response from each node confirms that the Ethernet connections are correct. For information about using the ping utility, refer to "Verifying Cluster Communications" in Chapter 5, "Installation and Configuration."
- To confirm that the shared storage is accessible to each cluster node, run Secure Path Manager or the Disk Management utility from each node. Confirm that the same RA4000/RA4100 Array disk volumes can be seen from each node. If the shared storage resources are not consistent across all nodes, refer to Appendix A, "Diagnosing and Resolving Shared Disk Problems" for more detailed guidelines.

Software Revisions

The following software components must have the same revision level on each of the cluster nodes:

- Oracle8*i* Server Release 8.1.7 with Oracle8*i* Parallel Server Option Release 8.1.7
- RA4000 Array Controller drivers
- Compaq Insight Manager
- Compaq Array Configuration Utility
- Compaq Secure Path for Windows 2000
- Compaq Ethernet OSDs
- Cluster interconnect drivers
- Microsoft Windows 2000 Advanced Server, including Service Pack 1 or later

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For information about currently supported software revisions for the PDC/O2000, refer to the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* at

www.compaq.com/solutions/enterprise/ha-pdc.html

Depending on your specific configuration, other software (for example, customer applications such as packet utilities) might exist that should be of the same revision level. If the same software is used on all the cluster nodes and either assists with the cluster's operation or takes advantage of clustering, the revision level should be the same.

Firmware Revisions

The firmware level must be identical for each of the following cluster components:

- The system ROM on each ProLiant server
- Firmware for the RA4000 Array Controllers

For information about currently supported firmware revisions for the PDC/O2000, refer to the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* at

www.compaq.com/solutions/enterprise/ha-pdc.html

Depending on your specific configuration, other firmware might exist that must be of the same revision level. A determining factor is whether or not the hardware device is part of a path that is accessible by more than one cluster node, more than one RA4000/RA4100 Array, or more than one client computer. If so, it is required that the firmware level of the hardware devices be identical.

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Troubleshooting Oracle8*i* and OSD Installation Problems and Error Messages

Potential Difficulties Installing the OSDs with the Oracle Universal Installer

- The Oracle Universal Installer (OUI) uses an inventory file to track which components of the OSDs have been installed on each of the cluster nodes. A single inventory file is maintained on the node from which the OUI was initially run. All subsequent uses of the OUI must be made from that same installing node.
- Installing onto a cluster node that already contains some or all of the OSD components will likely result in an incomplete installation. If difficulties persist, contact your support representative for assistance.
- The OUI uses the network connections to transfer files from the primary node to the other cluster nodes. Use the ping utility to ensure that proper node-to-node connectivity exists.
- The OUI requires administrator rights on all cluster nodes. To verify connectivity and access rights for each node, issue the following from the command line on the primary node:

  C: net use *machine_name*\C$ * /User: <*admin_login*>

  in which the "*" results in the system prompting you for a password, and the password is not echoed.

  If successful, the net use command returns:

  "The command completed successfully."

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- Determine whether or not you need to deinstall a partial OSD installation. An incomplete installation can result in a partial installation of the OSDs on the cluster. If this occurs, you must clean up after the partial installation (by removing it) before you can successfully run the OUI again. An incomplete OSD installation could result for various reasons, for example:
  - A cable is no longer seated tightly into its connector
  - The node from which you are running the OUI cannot communicate with all other nodes in the cluster
  - The user running the OUI does not bave administrator privileges on all cluster nodes

Refer to "Deinstalling a Partial OSD Installation" in Chapter 6, "Cluster Management," for information about how to remove a partial OSD installation.

Unable to Start OracleCMService

- Verify that the cluster interconnect is properly configured.
- Make sure the OSDs have been properly installed on the nodes by running the OUI on the cluster's primary node. Click **Installed Products** and verify that an entry for the OSDs exists.
- Verify that the OracleCMService has properly started by checking its error log. The default location for the error log is C:\compaq\ops\cmsvr.log. If not found in the default location, look in the same directory in which the OSD modules were installed.
- Verify that the Node Manager Service, OracleNMService, is running. If not, see the error logs in C:\compaq\ops\nm.log. If OracleNMService is running, check the CM Server logs in C:\compaq\ops\cmsrvr.log. Attempt to start the OracleCMService again.
- Check the event logs for errors. Be sure to check both the System and Application logs.

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Unable to Start OracleNMService

- Verify that the OracleNMService has properly started by checking the error log. The default location for the error log is C:\compaq\ops\nm.log. If not found in the default location, look in the same directory in which the OSD modules were installed.
- Verify that the Oracle8*i* software is correctly installed on all the nodes. Refer to Chapter 5, "Installation and Configuration," for an installation overview.
- Verify the connections and accessibility of the cluster components. Refer to the "Basic Troubleshooting Tips" section in this chapter.
- From the Event Viewer, check the event log for errors. Be sure to examine both the System and Application logs.

Unable to Start the Database

- Verify that Object Link Manager is properly installed and running on each node. Also, verify that Object Link Manager accurately sees all of the Oracle partitions and their symbolic link associations. Refer to "Installing Object Link Manager" in Chapter 5, "Installation and Configuration," and Appendix A, "Diagnosing and Resolving Shared Disk Problems" for detailed guidelines.
- Verify that all files created by Net8 Config Assistant were transferred properly to each respective node.
- Verify the connections and accessibility of the cluster components. Refer to the "Basic Troubleshooting Tips" section in this chapter.
- Verify that the OracleService is running. From the **Services** screen, scan the list of services and confirm that the OracleService is started.
- Verify that the database links are properly set up on all nodes and that correct entries exist for all datafiles, including OPS_CMDISK. Refer to the *Oracle8i Parallel Server Setup and Configuration Guide* for further details.

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Initialization of the Dynamic Link Library NM.DLL Failed

If this failure occurs, stop the currently running OracleCMService and OracleNMService. Restart the OracleNMService, then the OracleCMService. From Administrative Tools, open the **Services** screen. Locate each service in the displayed list, highlight it, then stop it. Finally, highlight the service and restart it.

Troubleshooting Node-to-Node Connectivity Problems

Nodes Are Unable to Communicate with Each Other

- Check the Windows 2000 Advanced Server event logs for errors.
- Check the OracleCMService error log for information. The default location for the error log is C:\compaq\ops\cmsrvr.log. If not found in the default location, look in the same directory in which the OSDs were installed.
- Verify the connections and accessibility of the cluster components. Refer to the "Basic Troubleshooting Tips" section in this chapter.
- The cluster interconnect must be on a separate subnet than the client LAN. Check this by viewing the IP addresses assigned to all interconnect adapters and to all client LAN adapters.
- If Compaq Insight Manager is loaded and configured, use it to check the operation statistics and possible error messages for the interconnect adapter installed in each cluster node.

When Using the Ethernet Cluster Interconnect

- Make sure that the Ethernet cluster interconnect components (adapters, cables, switches or hubs) are properly installed as specified in Chapter 5, "Installation and Configuration."
- Make sure that the Ethernet cluster interconnect and the client LAN are connected to different Ethernet switches or hubs.
- Use the ping utility to test the Ethernet cluster interconnect connections. For information about the ping utility, refer to "Verifying Cluster Communications" in Chapter 5, "Installation and Configuration."
- Make sure that all Ethernet traffic not related to the Oracle data is using the client LAN, not the cluster interconnect.

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Unable to Ping the Cluster Interconnect or the Client LAN

If you are using the recommended method of using static IP addresses, ensure that the hosts file and lmhosts files are properly set up.

When Using the Ethernet Cluster Interconnect

- Make sure that the Ethernet cables are properly connected and that the Ethernet switches or hubs are powered on. In a redundant Ethernet cluster interconnect, verify that all Ethernet adapters used as the primary cluster interconnect path are connected to the same switch and that all adapters used as the redundant cluster interconnect path are connected to the redundant switch.
- Make sure that the Ethernet drivers are properly installed and configured on the cluster nodes. Verify the Ethernet drivers for the interconnect adapters are the same revision level on all cluster nodes.
- If you are using two dual-port Ethernet adapters in each node to connect to both the client LAN and the Ethernet cluster interconnect, make sure that the cables are installed between the correct adapter ports and switches.

Node or Nodes Unable to Rejoin the Cluster

- If you have an Ethernet cluster interconnect, use ping to ensure that the rejoined node or nodes can communicate with other nodes in the cluster. For information about using the ping utility to test redundant Ethernet cluster interconnect connections, see "Verifying Cluster Communications" in Chapter 5, "Installation and Configuration."
- Make sure the OSDs have been properly installed on the affected node or nodes by running the OUI on the cluster's primary node. Click **Installed Products** and verify an entry for the OSDs exists.

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- Make sure the OracleCMService and all other Oracle services have started without error. From the **Services** screen, scan the list of services and check to see if the Oracle services have started. From the Application log, check for error messages about the Oracle services.
- Run Object Link Manager from each node to verify that the Oracle partitions and symbolic link associations are accurately displayed.
- Verify that the node or nodes have access to the shared storage. Run Disk Management and make sure that all the shared disk resources appear as expected. If the view is not consistent across all cluster nodes, refer to Appendix A, "Diagnosing and Resolving Shared Disk Problems."

Troubleshooting Client-to-Cluster Connectivity Problems

A Network Client Cannot Communicate with the Cluster

- Verify that the user ID has sufficient rights to perform the desired action.
- Make sure proper network connectivity exists by verifying that the connections from the network client to the cluster are cabled correctly. Additionally, verify that the network routers/switches/hubs used in the client LAN are powered on and properly cabled.
- Make sure that pinging an IP address over the client LAN from a client to the cluster issues a correct reply. Perform ping testing as described in the "Verifying Cluster Communications" section in Chapter 5, "Installation and Configuration."
- Make sure that the TNSNames.ora file is properly configured on client and cluster nodes as defined by the Oracle Net8 Config Assistant utility.
- Make sure that the Oracle TNSListener is running on the cluster nodes. From the **Services** screen, verify that Oracle TNSListener is started.
- Make sure that the Oracle Listener files are set up on the cluster nodes by using the Oracle TNSPing utility.
- Run Object Link Manager from each node to verify correct Oracle partitions and symbolic link associations. Refer to Appendix A, "Diagnosing and Resolving Shared Disk Problems," for detailed guidelines.

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Troubleshooting Shared Storage Problems

This section addresses potential problems arising from the use of RA4000 Arrays or RA4100 Arrays as the shared storage devices for the PDC/O2000. This section does not address RA4000/RA4100 Array problems that are specific to the product itself or to the use of the RA4000/RA4100 Array in a stand-alone server configuration. For those issues, refer to the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.

Verifying Connectivity to a Redundant Fibre Channel Fabric

To ensure that all I/O path connections in a redundant Fibre Channel Fabric are intact and functioning, verify the following:

- For each redundant Fibre Channel Fabric, at least two Fibre Host Adapters have been installed in the same PCI slots across all servers in the cluster.
- Verify that Fibre Channel cables are installed in the correct configuration between the Fibre Host Adapters installed in every server and their Fibre Channel SAN Switches. Refer to "Cabling the Fibre Host Adapters to the Storage Hubs or Switches" in Chapter 5, "Installation and Configuration," for cabling guidelines.
- Verify that the two array controllers in each RA4000/RA4100 Array are connected by Fibre Channel cable to different Fibre Channel SAN Switches. Refer to "Cabling the Storage Hubs or Switches to the RA4000/RA4100 Arrays" in Chapter 5, "Installation and Configuration," for cabling guidelines.

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Verifying Connectivity to a Redundant Fibre Channel Arbitrated Loop

To ensure that all I/O path connections in the redundant FC-AL are intact and functioning, verify the following:

- For each redundant FC-AL, at least two Fibre Host Adapters have been installed in the same PCI slots across all servers in the cluster.
- Verify that Fibre Channel cables are installed in the correct configuration between the Fibre Host Adapters installed in every server and their Storage Hubs or FC-AL Switches. Refer to "Cabling the Fibre Host Adapters to the Storage Hubs or Switches" in Chapter 5, "Installation and Configuration," for cabling guidelines.
- Verify that the two array controllers in each RA4000/RA4100 Array are connected by Fibre Channel cable to different Storage Hubs or FC-AL Switches. Refer to "Cabling the Storage Hubs or Switches to the RA4000/RA4100 Arrays" in Chapter 5, "Installation and Configuration," for cabling guidelines.

Shared Disks in the RA4000/RA4100 Arrays Are Not Recognized By One or More Nodes

If it appears that the shared disks in the RA4000/RA4100 Arrays are not properly recognized by one or more nodes, do the following:

- You may not have waited long enough to view the most up-to-date information. Wait a minute, then retry.
- Restart the affected node or nodes.
- Make sure that the Compaq StorageWorks Fibre Channel Host Adapter (Fibre Host Adapter) driver for Windows 2000 Advanced Server is installed and running on all cluster nodes. If it is not installed, refer to the *Compaq StorageWorks Fibre Channel Host Adapter Installation Guide* or the *Compaq StorageWorks 64-bit/66-MHz Fibre Channel Host Adapter Installation Guide* for installation instructions.
- Determine whether or not hardware errors or communications transport failures are causing the problem. Use the Event Viewer to verify that no hardware errors or transport problems exist. Check the event log for disk I/O error messages or indications of problems with the communications transport.

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- Determine whether or not the Compaq servers support the physical SCSI disks installed in the RA4000/RA4100 Arrays. Check the event log for disk I/O error messages or indications of problems with the communications transport.
- If the drives are still not recognized, it is recommended that you start investigating the problem from the lowest level of drive configuration.
  - Run the Compaq Array Configuration Utility. You can run this utility online if at least one logical drive is configured and recognized. The Array Configuration Utility is used to see if any of the drive arrays are offline (degraded or failed). The online utility is installed as part of the Compaq SmartStart and Support Software CD.
  - If all drives are not recognized by the Array Configuration Utility, it is probably a physical connection problem.
  - Verify that the indicator lights on the Fibre Host Adapters, Fibre Channel SAN Switches, FC-AL Switches, or Storage Hubs and RA4000 Array Controller are showing correct status.
  - Verify that the shortwave Gigabit Interface Converters (GBICs) are properly seated in the Fibre Host Adapters, Fibre Channel SAN Switches, FC-AL Switches, or Storage Hubs and RA4000 Array Controllers.
  - Verify that all Fibre Channel cables are properly connected to their Gigabit Interface Converter-Shortwave (GBIC-SW) modules. For details on how to connect the GBIC-SW modules and the Fibre Channel cables, refer to the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.
- If all drives are recognized by the Array Configuration Utility and are configured correctly, start Windows 2000 Advanced Server and run Disk Management. Verify that all drive volumes can be accurately viewed from Disk Management on each node.
- If you continue to have problems, refer to Appendix A, "Diagnosing and Resolving Shared Disk Problems," for further information. Also refer to the *Compaq Fibre Channel Troubleshooting Guide* for further corrective actions.

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A Cluster Node Cannot Connect to the Shared Drives

- Verify that a physical connection exists from each node to each Fibre Channel SAN Switch, FC-AL Switch, or Storage Hub.
  - Verify the shortwave Gigabit Interface Converter (GBIC) modules are properly seated in the affected Fibre Channel SAN Switch, FC-AL Switch, or Storage Hub, and RA4000 Array Controller.
  - Verify that all Fibre Channel cables are properly connected to their GBIC-SW modules.
- Verify all nodes can access the shared storage in the RA4000/RA4100 Arrays. On each node, start Disk Management to verify that the same shared disk resources are seen from every node in the cluster.
- The shared storage components must be powered on before the servers. If any cluster node was powered on before the Fibre Channel SAN Switches, FC-AL Switches, Storage Hubs, or the RA4000/RA4100 Arrays, shut down the node and restart.
- If the node is still unable to connect to the RA4000/RA4100 Arrays, refer to Appendix A, "Diagnosing and Resolving Shared Disk Problems."

Troubleshooting Secure Path

For detailed information about troubleshooting Secure Path software, refer to the troubleshooting documentation provided with Secure Path.

Secure Path Guidelines for Windows 2000 Advanced Server

The following rules and guidelines apply to the operation of Secure Path software in a PDC/O2000 cluster running Windows 2000 Advanced Server:

- Due to restrictions imposed by Secure Path, no more than eight logical drives (LUNs) can be assigned to each pair of RA4000 Array Controllers in an RA4000/RA4100 Array.
- There is no support for Windows 2000 dynamic disks.
- Windows NT fault-tolerant driver (for the host-based RAIDsets) cannot not be used in conjunction with Secure Path.

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- The same Secure Path Manager password must be used for all of the hosts in a profile.
- Before you change the Secure Path Agent's list of authorized clients or passwords, you must first manually stop the Secure Path Agent. Be sure to restart the Secure Path Agent after the changes have been completed.
- Before you modify device volume labels with the Disk Management, you must first manually stop the Secure Path Agent. After the modifications are competed, restart the Secure Path Agent to view the changes.
- Before you change the physical or logical configuration of your cluster's I/O path components, you must first stop the existing Secure Path Agent process (SecurePathAgent) from the **Services** screen. Examples of physical changes include adding, removing, or replacing a Fibre Host Adapter, Fibre Channel SAN Switch or Storage Hub, RA4000/4100 Array, RA4000 Array Controller, or shared disk drive. A logical change would include adding logical drives to your existing storageset. Be sure to verify that the Secure Path Agent is restarted after the changes have been completed.
- Before you replace an RA4000 Array Controller, you must also first shut down the affected node or nodes. After the replacement array controller has been installed, reboot the affected node or nodes and make sure that the Secure Path Agent is started.

Secure Path Manager Cannot Start With Hosts That Use Hyphenated Host Names

Secure Path Manager (SPM) is unable to start with hosts that use hyphenated host names (for example. *my-host*). Any hyphen indicates a cluster profile member to Secure Path Manager, and DNS will not be able to resolve the name correctly. Hyphenated host file names must be changed to unhyphenated names on all client systems.

To correct host names, add the name of the host without the hyphen to the Host file. Add this name to the client.ini file with the Agent configuration program, and use this name to log in with Secure Path Manager.

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Secure Path Manager Is Delayed In Reporting Path Failure Information

Due to extended error checking features present in the Secure Path software, there may be some delay with Secure Path Manager in reporting failed path information.

By default, the **Secure Path Manager** screen is refreshed every 60 seconds. To perform a manual refresh, press the **F5** key.

The Addition of New LUNs Causes an Error

In a PDC/O2000 cluster running Windows 2000 Advanced Server, the addition of new logical drives may cause the Add/Remove Hardware Wizard to display an error upon initializing the logical drive(s) and yellow warning indicators to be displayed from the Device Manager.

To cancel these error displays, reboot the affected server node or nodes.

A Configuration of More Than 64 LUNs Prevents the Secure Path Agent From Starting

A configuration of more than 64 LUNs may inhibit the Secure Path Agent from automatically starting. If this occurs, do the following:

1. From the **Services** screen, right click on **Secure Path Agent.**
2. Select **Properties,** then select **Recovery.**
3. Select **Recovery** to restart the Secure Path Agent after the first failure.
4. Click **Apply,** then click **OK.**

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Appendix A

Diagnosing and Resolving Shared Disk Problems

Introduction

When one or more nodes in a Compaq Parallel Database Cluster Model PDC/O2000 (referred to here as the PDC/O2000) cannot properly join the cluster, you need to consider two possible causes:

- A problem related to the shared disk storage in the cluster's Compaq StorageWorks RAID Array 4000s (RA4000 Arrays) or Compaq StorageWorks RAID Array 4100s (RA4100 Arrays) is preventing one or more nodes from accurately viewing or successfully accessing the available shared storage resources.
- A connectivity problem exists either within the cluster interconnect or the client LAN, preventing one or more nodes from communicating with the other nodes or preventing a client from communicating with the cluster.

This appendix describes the procedures you should follow to diagnose and resolve suspected shared disk problems in a PDC/O2000.

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Figure A-1 identifies, in a flowchart format, the sequence of tasks you should perform to diagnose, isolate, and resolve shared disk problems in a PDC/O2000. A detailed description of each task is provided in the following sections of this appendix.

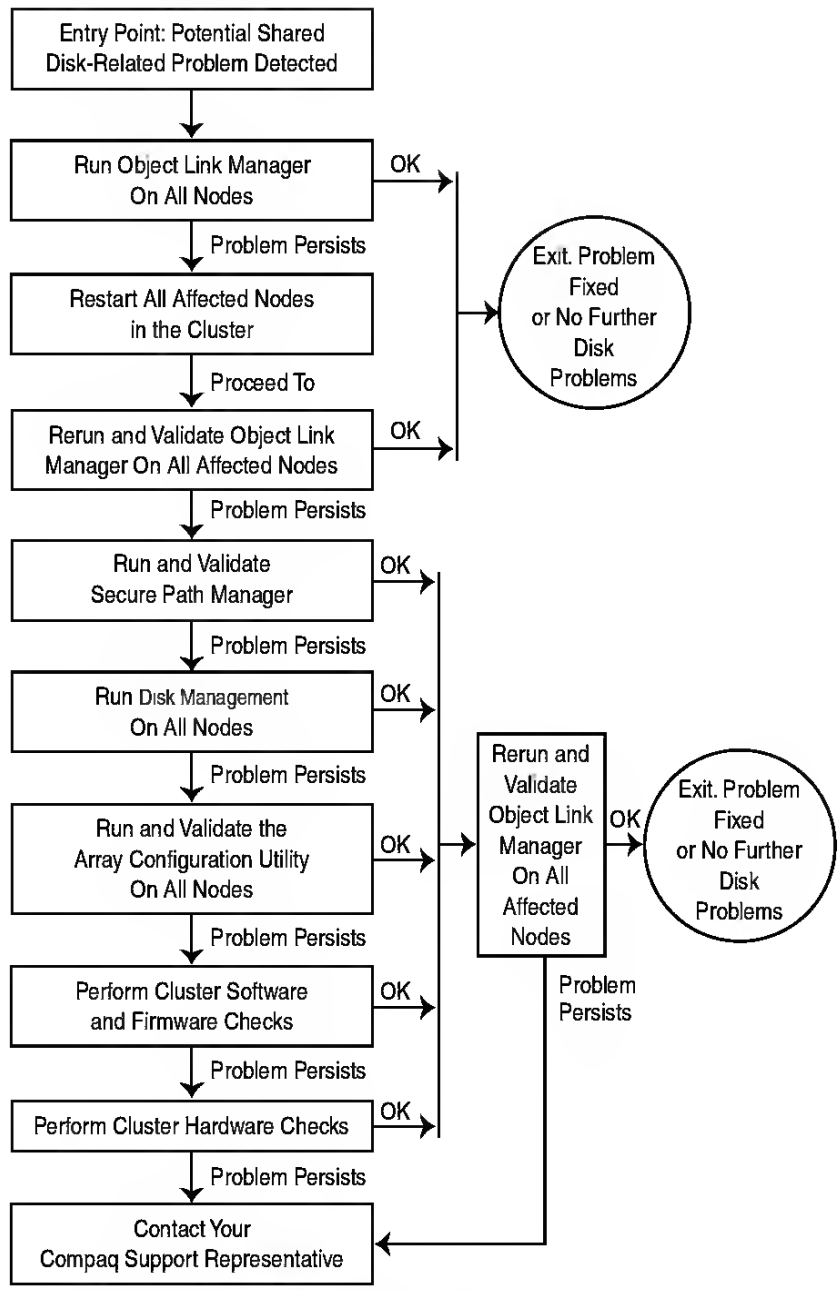
Entry Point: Potential Shared Disk-Related Problem Detected
Run Object Link Manager On All Nodes
OK
Problem Persists
Restart All Affected Nodes in the Cluster
Proceed To
Rerun and Validate Object Link Manager On All Affected Nodes
OK
Problem Persists
Exit. Problem Fixed or No Further Disk Problems
Run and Validate Secure Path Manager
OK
Problem Persists
Run Disk Management On All Nodes
OK
Problem Persists
Run and Validate the Array Configuration Utility On All Nodes
OK
Problem Persists
Perform Cluster Software and Firmware Checks
OK
Problem Persists
Perform Cluster Hardware Checks
OK
Problem Persists
Contact Your Compaq Support Representative
Rerun and Validate Object Link Manager On All Affected Nodes
OK
Exit. Problem Fixed or No Further Disk Problems
Problem Persists

Figure A-1. Tasks for diagnosing and resolving shared storage problems

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Run Object Link Manager on All Nodes

Object Link Manager simplifies the creation and maintenance of symbolic links between disk partitions and Oracle data files by placing the symbolic link names directly onto the disk partitions, thereby tracking the symbolic links dynamically. This means that if the order in which disk drives are brought online changes, Oracle8*i* Server can find the correct data files and can properly start the Oracle database.

Object Link Manager also provides a detailed view of the Oracle partitions and their symbolic link associations in the cluster's shared storage.

To view the shared storage information from Object Link Manager, perform these tasks:

1. From each node, run the GUI associated with Object Link Manager.
2. Verify that it runs properly and displays no errors. If necessary, use the online help facility to assist you in your navigation of Object Link Manager.
3. Verify that Object Link Manager can see all Oracle partitions and their symbolic link associations and that this view is consistent across all nodes.
4. Repeat steps 1 through 3 on all other nodes in the cluster.
5. If Object Link Manager does not run properly or displays incorrect Oracle partition and symbolic link information on one or more nodes, proceed to "Restart All Affected Nodes in the Cluster" in this appendix for further instructions.

For instructions on installing and using Object Link Manager, see the readme file:

```
\Object Link Manager\readme.txt
```

This file is located on the Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Microsoft Windows 2000 CD.

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Restart All Affected Nodes in the Cluster

If Object Link Manager does not run properly on one or more nodes or does not provide consistent information about Oracle partitions and symbolic links from all nodes, perform these steps:

1. Identify the node or nodes on which Object Link Manager either does not run properly or does not present the correct information about Oracle partitions and symbolic links.
2. Restart each affected node.
3. Proceed to "Rerun and Validate Object Link Manager On All Affected Nodes" in this appendix for further instructions.

Rerun and Validate Object Link Manager On All Affected Nodes

Perform these steps from every node on which Object Link Manager does not run properly:

1. Verify that the Object Link Manager service is properly installed on the node. For instructions on installing and using Object Link Manager, refer to this readme file contained on the Compaq Parallel Database Cluster Clustering Software for Oracle8*i* on Windows 2000 CD:

   \Object Link Manager\readme.txt
2. Verify that the correct symbolic link names have been used for the shared disk partitions.
3. Restart the Object Link Manager service.
4. Repeat steps 1 through 3 for all nodes in the cluster.

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Run and Validate Secure Path Manager On All Nodes

The **Secure Path Manager** screens provide information about the shared storage resources in the cluster, including RA4000/RA4100 Array storagesets, array controller path configurations, drive lettering, and volume labels.

To run and validate Secure Path Manager, perform these steps from each node:

1. Use the **Secure Path Manager** screens to verify that every storageset is visible and that all logical disks and RA4000 Array Controllers are correctly and consistently defined across all nodes. Also confirm that the attributes associated with the shared disks are consistent across all nodes. Refer to the documentation provided with the Secure Path software for detailed information about **Secure Path Manager** screens.
2. Verify that the version number for Secure Path Manager is correct. Refer to the *Compaq Parallel Database Cluster Model PDC/O2000 Certification Matrix for Windows 2000* for version information.
3. Verify that Secure Path Manager has been properly installed on the node. Refer to "Installing Secure Path Software for Windows 2000" in Chapter 5, "Installation and Configuration," for installation instructions.
4. Repeat steps 1 through 3 for all nodes in the cluster.

Run Disk Management On All Nodes

Perform these steps from each node:

1. From Disk Management, verify that each RA4000 Array or RA4100 Array is visible.
2. Verify that all shared drive information (drive letters, volume labels, number of partitions, partition sizes, etc.) is consistent across all nodes.
3. Repeat steps 1 and 2 for all nodes in the cluster.

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Run and Validate the Array Configuration Utility On All Nodes

The Array Configuration Utility is used to configure the hardware aspects of disk drives connected to the RA4000 Array Controllers. The Array Configuration Utility allows you to configure RAID levels and to add disk drives or RA4000/RA4100 Arrays to an existing configuration. Like Disk Management and Redundancy Manager, it also provides each node with a detailed view of the shared storage resources in the cluster.

To run and validate the Array Configuration Utility from each node, perform these steps:

1. From the Array Configuration Utility, verify that all RA4000/RA4100 Arrays and their logical disks are visible and consistent across all nodes.
2. Verify that each RA4000/RA4100 Array's serial number for all shared disks is consistent across all nodes.
3. Verify that the RAID configurations of RA4000/RA4100 Array shared disks are consistent across all nodes.
4. Repeat steps 1 through 3 for all nodes in the cluster.

Perform Cluster Software and Firmware Checks

Use the Compaq SmartStart and Support Software CD to perform these checks on the cluster software and firmware:

1. Verify that all necessary drivers have been installed. For example, verify that the Compaq StorageWorks Fibre Channel Host Adapter (Fibre Host Adapter) driver for Windows 2000 Advanced Server is installed and running on all cluster nodes. Refer to Chapter 5, "Installation and Configuration," for driver installation guidelines.
2. Verify that that the version levels for all drivers, including those for Fibre Host Adapters and RA4000 Array Controllers, are correct and consistent across all nodes.
3. Verify that all firmware versions, including those for the system ROM on each server, the Fibre Host Adapter firmware, and the RA4000 Array Controller firmware, are correct and consistent across all nodes.

NOTE: For information about supported software and firmware, refer to the *Compaq Parallel Database Cluster Model PDC/D2000 Certification Matrix for Windows 2000* at www.compaq.com/solutions/enterprise/ha-pdc.html

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Perform Cluster Hardware Checks

Validate the cluster hardware by performing these steps:

1. Determine whether or not hardware errors or communications transport failures might be causing the problem. Use the Event Viewer to verify that no hardware errors or transport problems exist. Check the event log for disk I/O error messages or indications of problems with the communications transport.
2. Determine whether or not the Compaq servers support the physical SCSI disks that are installed in the RA4000/RA4100 Arrays. Check the event log for disk I/O error messages or indications of problems with the communications transport.
3. Verify that the indicator lights on the Fibre Host Adapters, Compaq StorageWorks Storage Hubs, Compaq StorageWorks FA-AL Switches, or Compaq StorageWorks Fibre Channel SAN Switches, and RA4000 Array Controllers are all in the correct state.
4. Verify that the Gigabit Interface Converter-Shortwave (GBIA-SW) modules are all the correct brand or model type and are properly seated in the Fibre Host Adapters, Fibre Channel SAN Switches, Storage Hubs, or FA-AL Switches, and RA4000 Array Controllers.
5. Inspect all Fibre Channel cables to verify that they are in good condition and have no breaks or excessive bends.
6. Verify that the Fibre Channel cables are properly connected to the GBIA-SW modules in the Fibre Host Adapters, Fibre Channel SAN Switches, Storage Hubs, or FA-AL Switches, and RA4000 Array Controllers. For details on how to connect the GBIA-SW modules and the Fibre Channel cables, refer to the *Compaq StorageWorks RAID Array 4000 User Guide* or the *Compaq StorageWorks RAID Array 4100 User Guide*.
7. Verify that all Fibre Host Adapters, RA4000 Array Controllers, and RA4000/RA4100 Array shared disk modules are properly installed and seated in their receptacles.

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Contact Your Compaq Support Representative

If you are unable to resolve the problem, contact your Compaq support representative for assistance.

In North America, call the Compaq Technical Support Phone Center at 1-800-OK-COMPAQ. Outside North America, call the nearest Compaq Technical Support Phone Center. Telephone numbers for worldwide Technical Support Centers are listed on the Compaq website at

www.compaq.com

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Glossary

Availability A measure of how well a computer system can deliver services to its clients continuously. Availability is typically expressed as a percentage, with 100 percent being the best possible rating.

Client LAN A local area network dedicated to servicing requests between network client machines and between the cluster nodes and the client machines. This is different than a cluster interconnect, which is dedicated to servicing information requests to and from cluster nodes only.

Cluster An integration of software and hardware technologies that enables a set of loosely coupled servers and storage to present a single system image to clients and to operate as a single system. Clustering is a way to improve availability and scalability.

Downtime The period of time that a computer system is unable to service clients' requests.

Ethernet A standard network protocol that operates mostly on a physical level, using network interface cards and cabling to transmit data between computers. Transfer rates are normally 10 or 100 megabits per second.

Fault tolerance A characteristic that allows continued operation of a computer entity when a fault (or failure) is encountered. Fault tolerance applies to a computer component, an individual computer, or a cluster of computers, primarily through designing redundant elements into the entity.

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Fibre Channel	An IEEE standard for providing high-speed data transfer among workstations, mainframes, supercomputers, desktop computers, storage devices, and display devices.
Fibre Channel Arbitrated Loop (FC-AL)	A data path from the Fibre Host Adapters in the cluster nodes to the array controllers in the RA4000 Arrays or RA4100 Arrays. A PDC/O2000 requires one or more redundant FC-ALs. Each FC-AL is redundant because there are at least two paths from each node to each RA4000/RA4100 Array.
Fibre Channel Fabric	A storage area network (SAN) topology that uses Fibre Channel SAN Switches to connect cluster nodes with shared storage resources.
GBIC-SW module	Gigabit Interface Converter-Shortwave module. A module installed at both ends of a Fibre Channel cable.
Heartbeat	A signal transmitted between cluster nodes to indicate whether the nodes are operating.
High availability	A term used to identify a computer system that can continuously deliver services to its clients 99.9 percent of the time (no more than 8.5 hours of downtime per year).
Hot-pluggable	A computer component that can be removed and replaced without powering down the system.
Hot spare	A computer component that is powered on, not actively processing data, and awaiting a request to take over operation of a failed component.
Interconnect	A physical connection between cluster nodes that transmits intra-cluster communication, also called the cluster heartbeat. The Compaq Parallel Database Cluster interconnect is dedicated to servicing requests only between cluster nodes.
Integrated Distributed Lock Manager	An Oracle software component that coordinates database locks among cluster nodes. Sometimes abbreviated as IDLM.
IP Address	Internet Protocol Address. An address assigned to a network interface card, which computer entities use to locate and communicate with each other. IP addresses can be statically or dynamically assigned.
LAN	Local Area Network.

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Load balancing	To balance the amount of work (processing) undertaken by each node in a cluster.
NIC	Network Interface Controller. A board that allows a computer to be connected with a network, and works with the network operating system to control the flow of information over the network.
Node	An individual server in a cluster.
NTFS	New Technology File System. A file organization system by which data is stored and accessed in a Microsoft Windows NT operating system.
Operating System Dependent (OSD) layer	A collection of low-level software modules that monitors critical clustering hardware components and constantly transmit/receive cluster state information to and fromOracle8*i* Parallel Server.
Oracle Parallel Server Option	A software component that ships as an option of Oracle8*i* Enterprise Edition. The component is responsible for enabling parallel database support. An additional license is required for Oracle8*i* Parallel Server.
Oracle Universal Installer	An installation application used to install and de-install both Oracle8*i* software and the hardware vendor's Operating System Dependent modules for Oracle8*i*.
POST	Power-On Self-Test. A set of operations executed every time a system is turned on to verity that components are present and operating.
Raw partition	A disk partition that does not contain file system formatting information. An unformatted partition. Oracle Parallel Server requires its database files to be stored on raw partitions.
RAID	Redundant Array of Inexpensive Disks. A method of using hard disk drives in an array to provide data redundancy to increase system reliability and performance. RAID is categorized into several levels.
Reliability	The continuous integrity of a system (server, storage, network, or cluster).
Resource	A software or hardware entity upon which a client/server application or service is dependent. As it pertains to the PDC/O2000, a cluster resource must have the ability to be managed by the cluster and must reside on one of the cluster nodes.

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Scalability	The ability of a system (server, storage, network, or cluster) to grow or expand in performance, throughput, or capacity.
Secure Path	The Compaq software that provides cluster nodes with continuous data access to RA4000/RA4100 Array disks drives. Secure Path monitors each I/O path and automatically reroutes I/O to the defined backup path should a failure occur in any component along an active path.
Service	A data set or operation set exported by application servers to their clients.
Shared resource	A type of cluster organization in which some resources are accessible to all systems in the cluster.
Shared storage	A storage system that can be simultaneously accessed by multiple nodes in a PDC/O2000 cluster. The RA4000 Arrays or RA4100 Arrays house the shared storage for the PDC/O2000.
System	A complete computer system capable of operating independently. A system can be either a single processor system or an SMP system. Example: a server.
UPS	Uninterruptible power supply.

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